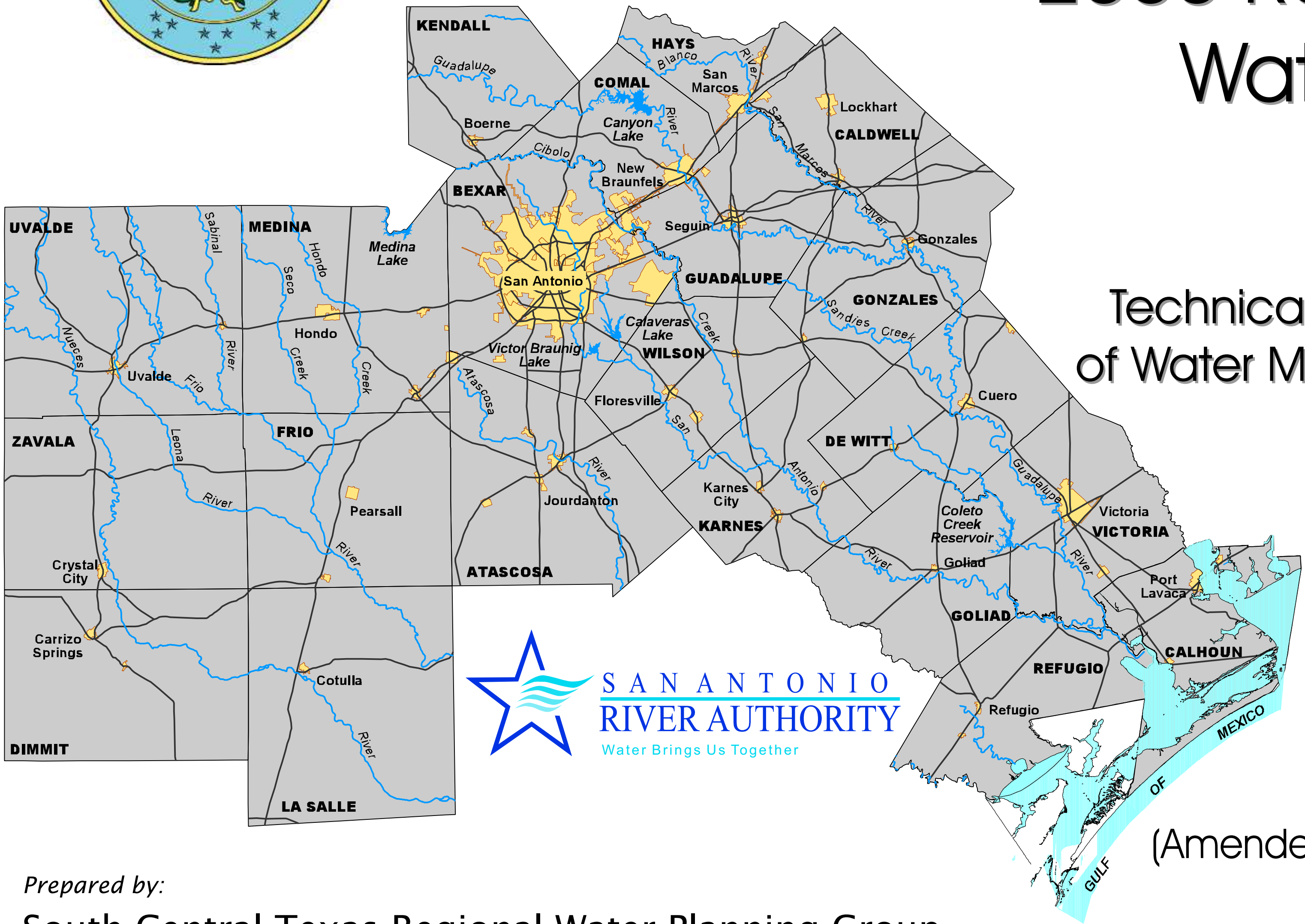
South Central Texas Regional Water Planning Area

2006 Regional Water Plan

Volume II Technical Evaluations of Water Management Strategies



January 2006
(Amended August 2009)

Prepared by:

South Central Texas Regional Water Planning Group

With administration by:

San Antonio River Authority

With technical assistance by:

HDR Engineering, Inc.
Margaret Dalthorp

In association with:

Paul Price Associates, Inc.
John Folk-Williams

HDR ONE COMPANY *Many Solutions*[SM]

South Central Texas Regional Water Planning Area

2006 Regional Water Plan

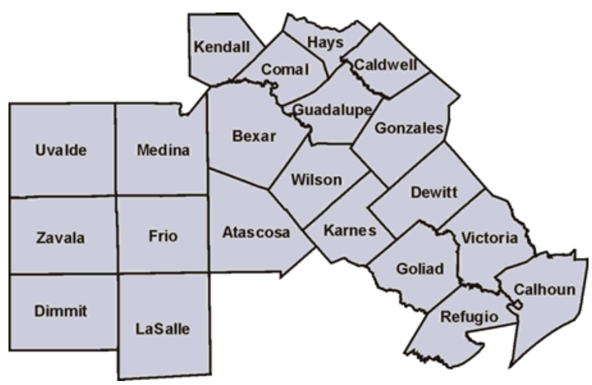
Volume II — Technical Evaluations of Water Management Strategies

Prepared by:

South Central Texas Regional Water Planning Group

With administration by:

San Antonio River Authority



With technical assistance by:

HDR Engineering, Inc.
Margaret Dalthorp

In association with:

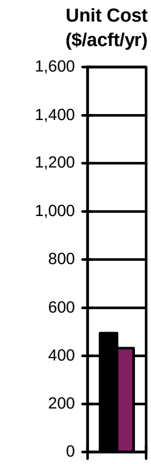
Paul Price Associates, Inc.
John Folk-Williams

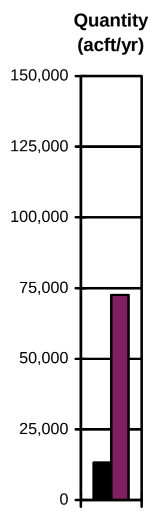
January 2006
(Amended August 2009)

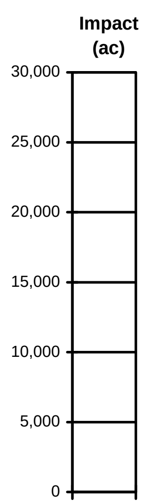
Table of Contents

Table of Contents (Concluded)

Appendices







Name: Municipal Water Conservation (Demand Reduction) (L-10 Mun.)

Description: Best Management Practices of plumbing fixture and clothes washer retrofit, and urban lawn and landscape irrigation efficiency improvements in residential, commercial, and institutional establishments to reduce municipal per capita water use in addition to reductions already incorporated into the TWDB municipal water demand projections.

Decade Needed**:** 2000 – 2060.

Cost, Quantity of Water, and Land Impacted

Unit Cost of Water:	**494 – 432**	**$/acft/yr[1]**	**Water demand reduced.**
Quantity of Water:	**13,213 – 72,570**	**acft/yr[2]**	**Reliability = Firm**
Land Impacted:	**0**	**acres**	**[1 & 2]Unit cost and quantity of water at 2010 and 2060**

Additional Considerations per Regional Water Planning Guidelines

Environmental Factors: Needs are met through municipal water demand reduction. Avoids water supply development that requires additional land and other resources.

Impacts on Water Resources: Slight reductions in treated effluent discharged from municipal systems are possible, depending upon relative rate of growth in demand and conservation effectiveness.

Impacts on Agricultural & Natural Resources: Needs are met through municipal water demand reduction (see Environmental Factors above), and would not affect quantity or quality of fresh water for agriculture and natural resources, with the possible exception of small reductions in discharge of treated municipal effluent that may result in reduced streamflows.

Other Relevant Factors per SCTRWPG: Water conservation is central to regional water plan, and is encouraged for all uses.

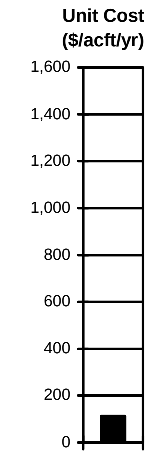
Comparison of Strategies to Meet Needs: Relatively low cost in comparison to conventional water supply strategies. No conflicts with other water management strategies.

Interbasin Transfer Issues: Means of achieving highest practicable level of conservation for recipients of planned interbasin transfer.

Third-Party Impacts of Voluntary Transfers: Not applicable.

Regional Efficiency: Allows existing water supplies to serve more population. Water use efficiency is increased throughout the region.

Water Quality Considerations: None of significant concern.



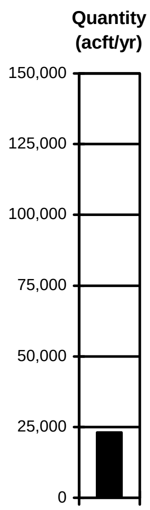
Name: Irrigation Water Conservation (Demand Reduction) (L-10 Irr.)

Description: Best Management Practices of Low Energy Precision Application (LEPA) in conjunction with Furrow Dikes to reduce irrigation rates by 20 percent per acre on 75 percent of year 2000 irrigated acres in counties having irrigation needs.

Decade Needed: 2000 – 2060: Applicable to major irrigation areas of the region.

Cost, Quantity of Water, and Land Impacted

Unit Cost of Water:	**113**	**$/acft/yr[1]**	**Water demand reduced.**
Quantity of Water:	**23,074**	**acft/yr[2]**	**Reliability = Firm**
Land Impacted:	**0**	**acres**	**[1 & 2]Unit cost and quantity of water at 2010 (Atascosa, Bexar, Medina, and Zavala Cos.)**

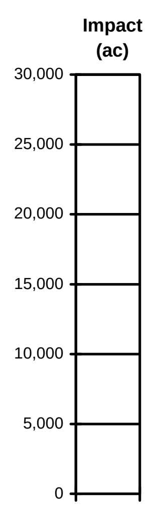


Additional Considerations per Regional Water Planning Guidelines

Environmental Factors: Needs are met through irrigation water demand reduction on acres equipped with LEPA, thereby freeing up water to irrigate acreages having water shortages. Avoids water supply development that requires additional land and other resources (see Impacts on Agricultural & Natural Resources below).

Impacts on Water Resources: Improved water application efficiency per acre irrigated results in reduced water demands per acre, thereby contributing to meeting projected needs for irrigation.

Impacts on Agricultural & Natural Resources: Needs are met through improved irrigation application efficiencies, and would allow existing quantity of fresh water used for irrigated agriculture to meet projected demands. This strategy would not affect the quantity or quality of fresh water for natural resources.



Other Relevant Factors per SCTRWPG: Water conservation is central to regional water plan, and is encouraged for all uses.

Comparison of Strategies to Meet Needs: Relatively low cost in comparison to conventional water supply strategies. No conflicts with other water management strategies.

Interbasin Transfer Issues: Not applicable.

Third-Party Impacts of Voluntary Transfers: Not applicable.

Regional Efficiency: Allows existing water supplies to meet projected demands in Atascosa, Bexar, and Medina Counties. Needs of Zavala County cannot be met through irrigation water conservation.

Water Quality Considerations: Through use of BMPs, there is potential to reduce runoff from irrigated land, thereby reducing instream nutrient and contaminant loading.

Section 4C
Technical Evaluations of Water Management Strategies

4C.1 Water Conservation (Demand Reduction) (L-10)

A significant water management strategy is to increase water conservation and thereby reduce freshwater use within the planning area. The general methods to accomplish this objective are to: (1) reduce per capita water use in the municipal water use category; (2) recycle and reuse industrial water and substitute reclaimed water (treated municipal and industrial wastewater) for use in some industries, steam-electric power generation, and irrigation; and (3) improve irrigation efficiencies to reduce the quantity of water use in agriculture per acre irrigated. Best Management Practices (BMPs) for water conservation, as identified by the Water Conservation Implementation Task Force, will be used in the water conservation water management strategy.[1] In addition, estimates will be made of the water conservation potentials and associated costs of water conservation for municipal and irrigation water user groups.

4C.1.1 Municipal Water Conservation (L-10 Mun.)

For regional water planning purposes, municipal water use is defined as residential and commercial water use. Municipal water supply is used primarily for drinking, sanitation, cleaning, cooling, fire protection, and landscape watering for residential, commercial, and institutional establishments. Such water is supplied by both public and private utilities, and in areas not served by water utilities, is supplied by individual households. A key parameter of municipal water use within a typical city or water service area is the number of gallons used per person per day (per capita water use). The objective of municipal water conservation programs is to reduce the per capita water use parameter without adversely affecting the quality of life of the people involved. This can be achieved through:

- Use of low flow plumbing fixtures (e.g., toilets, shower heads, and faucets that are designed for low quantities of flow per unit of use);
- The selection and use of more efficient water-using appliances (e.g., clothes washers and dishwashers);
- Modifying and/or installing lawn and landscaping systems to use grass and plants that require less water;
- Repair of plumbing and water-using appliances to reduce leaks; and

[1]Water Conservation Implementation Task Force, Report to the 79th Legislature, Texas Water Development Board, Special Report, Austin, Texas, November 2004.

- Modification of personal behavior that controls the use of plumbing fixtures, appliances, and lawn watering methods.

With respect to plumbing fixtures, in 1991 the Texas Legislature enacted Senate Bill 587, which established minimum standards for plumbing fixtures sold in Texas.[2] The bill became effective on January 1, 1992, and allowed for wholesalers and retailers to clear existing inventories of pre-standards plumbing fixtures by January 1, 1993. The standards for new plumbing fixtures, as specified by Senate Bill 587, are shown in Table 4C.1-1. The Texas Commission on Environmental Quality (TCEQ) has promulgated rules requiring the labeling of both plumbing fixtures and water-using appliances sold in Texas. The labels must specify the rates of flow for plumbing fixtures and lawn sprinklers, and the amounts of water used per cycle for clothes washers and dishwashers.[3]

Table 4C.1-1.
Standards for Plumbing Fixtures

Fixture	*Standard*
Wall-mounted Flushometer Toilets	2.00 gallons per flush
All Other Toilets	1.60 gallons per flush
Shower Heads	2.75 gallons per minute at 80 psi
Urinals	1.00 gallon per flush
Faucet Aerators	2.20 gallons per minute at 80 psi
Drinking Water Fountains	Shall be self-closing

The TWDB has estimated that the effect of the new plumbing fixtures in dwellings, offices, and public places will be a reduction in per capita water use of 18 gallons per capita per day (gpcd), in comparison to what would have occurred with previous generations of plumbing fixtures.[4] The estimated water conservation effect of 18 gpcd was obtained using the data found in Table 4C.1-2.

In 2001, the Texas Legislature amended the Texas Water Code to require Regional Water Planning Groups to consider water conservation and drought management measures for

[2] Senate Bill 587, Texas Legislature, Regular Session, 1991, Austin, Texas.
[3] Chapter 290, 30 TAC Sections 290.251, 290.253 - 290.256, 290.260, 290.265, 290.266, Water Hygiene, Texas Register, Page 9935, December 24, 1993.
[4] "Water Conservation Impacts on Per Capita Water Use," Water Planning Information, Texas Water Development Board, Austin, Texas, 1992.

Table 4C.1-2.
Water Conservation Potentials of Low Flow Plumbing Fixtures[1]

Plumbing Fixture	***Water Savings (gpcd)***
Toilets – 1.6 gallons per flush	11.5
Shower Heads – 2.75 gallons per minute	4.0
Faucet Aerators – 2.2 gallons per minute	2.0
Urinals – 1.0 gallon per minute	0.3
Drinking Fountains (self-closing)	0.1
Total	17.9 (18 gpcd)

[1] Texas Water Development Board, 1992.

each water user group with a need (projected water shortage). The Water Conservation Implementation Task Force has identified and described Water Conservation BMPs and provided a BMP Guide for use by Regional Water Planning Groups in the development of the 2006 Regional Water Plans.[5] The list of BMPs for municipal water users is as follows:

1. System Water Audit and Water Loss;
2. Water Conservation Pricing;
3. Prohibition on Wasting Water;
4. Showerhead, Aerator, and Toilet Flapper Retrofit;
5. Residential Ultra-Low Flow Toilet Replacement Programs;
6. Residential Clothes Washer Incentive Program;
7. School Education;
8. Water Survey for Single-Family and Multi-Family Customers;
9. Landscape Irrigation Conservation and Incentives;
10. Water-Wise Landscape Design and Conversion Programs;
11. Athletic Field Conservation;
12. Golf Course Conservation;
13. Metering of all New Connections and Retrofitting of Existing Connections;
14. Wholesale Agency Assistance Programs;
15. Conservation Coordinator;
16. Reuse of Reclaimed Water;
17. Public Information;
18. Rainwater Harvesting and Condensate Reuse;
19. New Construction Graywater;
20. Park Conservation; and
21. Conservation Programs for Industrial, Commercial, and Institutional Accounts.

[5] Water Conservation Implementation Task Force, Report to the 79th Legislature, Texas Water Development Board, Special Report, Austin, Texas, November 2004.

In addition to the list of BMPs, the Water Conservation Implementation Task Force recommends that a standardized methodology be used for determining per capita per day municipal water use in order to allow consistent evaluations of effectiveness of water conservation measures among cities that are located in the different climates and parts of Texas. The Task Force further recommends gpcd targets and goals that should be considered by retail public water suppliers when developing water conservation plans required by the state, as follows:

- "All public water suppliers that are required to prepare and submit water conservation plans should establish targets for water conservation, including specific goals for per capita water use and for water loss programs using appropriate water conservation BMPs.
- "Municipal Water Conservation Plans required by the state shall include per capita water-use goals, with targets and goals established by an entity giving consideration to a minimum annual reduction of one percent in total gpcd, based upon a five-year moving average, until such time as the entity achieves a total gpcd of 140 gpcd or less."

For the 2006 Regional Water Plan, The South Central Texas Regional Water Planning Group established the municipal water conservation goals, as follows:

- For municipal WUGs with water use of 140 gpcd and greater, the goal is to reduce per capita water use by one percent per year until the level of 140 gpcd is reached, after which, the goal is to reduce per capita water use by one-fourth percent per year for the remainder of the planning period; and
- For municipal WUGs having year 2000 water use of less than 140 gpcd, the goal is to reduce per capita water use by one-fourth percent per year (0.25% per year).

The 130 Municipal WUGs of Region L are listed in Table 4C.1-3, in the order of lowest to highest per capita water use in year 2000 together with projected per capita water use with expected effects of low flow plumbing fixtures upon per capita water use in 2010, 2020, 2030, 2040, 2050, and 2060. This table shows the water conservation effects of low flow plumbing fixtures that were included in the projected water demands for each WUG. The projected municipal water needs (shortages) were calculated for each WUG by subtracting projected municipal water demands from existing municipal water supplies, with the low flow plumbing fixture water conservation effects taken into account.

Table 4C.1-3.
Municipal Water User Groups
Projected Per Capita Water Use with Low Flow Plumbing Fixtures
South Central Texas Water Planning Region

County Number	Water User Group*	County	Per Capita Water Use with Low Flow Plumbing Fixtures 2000 (gpcd)	2010 (gpcd)	2020 (gpcd)	2030 (gpcd)	2040 (gpcd)	2050 (gpcd)	2060 (gpcd)
1	Calhoun County WS	Calhoun	71	66	64	62	61	60	60
2	County-Other	Wilson	81	78	76	75	74	74	74
3	Green Valley SUD	Guadalupe	85	80	77	76	74	74	74
4	Polonia WSC	Caldwell	87	82	79	77	76	75	75
5	County-Other	Victoria	91	87	84	82	80	79	79
6	Benton City WSC	Atascosa	94	90	88	87	86	86	86
7	County-Other	Dimmit	96	93	90	87	84	83	83
8	County-Other	Goliad	98	94	92	89	87	86	86
9	Creedmoor-Maha WSC	Caldwell	98	94	90	88	87	86	86
10	Goforth WSC	Hays	99	93	91	89	88	88	88
11	Crystal Clear WSC	Guadalupe	100	95	92	91	89	89	89
12	Martindale	Caldwell	100	97	93	90	87	86	86
13	Plum Creek Water Co.	Hays	100	95	92	90	89	89	89
14	County-Other	Refugio	101	99	96	93	89	87	87
15	McCoy WSC	Atascosa	101	97	95	93	92	92	92
16	Atascosa Rural WSC	Bexar	102	96	93	91	90	89	89
17	County-Other	Atascosa	102	102	102	99	93	88	88
18	County-Other	Kendall	102	96	94	92	91	91	91
19	Wimberley WSC	Hays	102	98	95	93	91	91	91
20	Kirby	Bexar	103	99	95	92	89	88	88
21	County-Other	Dewitt	105	102	99	96	93	91	91
22	County-Other	Frio	105	101	97	95	93	92	92
23	Karnes City	Karnes	108	104	101	98	96	95	95
24	Leon Valley	Bexar	108	105	102	99	96	94	94
25	Maxwell WSC	Caldwell	108	103	99	98	96	96	96
26	Live Oak	Bexar	110	106	102	99	96	95	95
27	SS WSC	Wilson	110	104	102	100	99	99	99
28	County-Other	Gonzales	111	110	108	105	100	97	97
29	County-Other	Guadalupe	112	110	107	104	100	98	98
30	Santa Clara	Guadalupe	114	110	108	108	107	107	107
31	County-Other	Bexar	115	113	111	109	107	106	106
32	East Medina WSC	Medina	115	111	108	106	104	103	103
33	Converse	Bexar	116	111	107	105	104	103	103
34	County-Other	Comal	116	112	109	106	103	102	102
35	Niederwald	Hays	116	113	111	111	110	110	110
36	Bexar Met Water District	Bexar	118	114	111	108	105	104	104
37	Kyle	Hays	118	114	113	112	111	111	111
38	Bulverde City	Comal	120	116	114	113	113	113	113
39	County-Other	Uvalde	122	118	115	113	112	111	111
40	East Central WSC	Bexar	122	116	113	111	110	109	109
41	St. Hedwig	Bexar	122	117	113	111	109	108	108

Continued on next page

Table 4C.1-3 Continued

County Number	Water User Group*	County	Per Capita Water Use with Low Flow Plumbing Fixtures						
			2000 (gpcd)	2010 (gpcd)	2020 (gpcd)	2030 (gpcd)	2040 (gpcd)	2050 (gpcd)	2060 (gpcd)
42	Aqua WSC	Caldwell	123	118	115	112	111	110	110
43	Port Lavaca	Calhoun	123	120	117	114	111	110	110
44	Marion	Guadalupe	125	121	118	115	113	112	112
45	Waelder	Gonzales	125	122	119	116	115	114	114
46	County-Other	Medina	129	126	124	122	121	121	121
47	Water Ser Inc (APEX)	Bexar	129	124	121	119	118	117	117
48	Woodcreek	Hays	132	127	125	123	121	121	121
49	Elmendorf	Bexar	133	129	125	122	120	119	119
50	County-Other	La Salle	134	132	129	128	126	126	126
51	County-Other	Calhoun	135	131	128	125	122	121	121
52	Lacoste	Medina	135	131	127	125	122	121	121
53	Yorktown	Dewitt	135	132	129	126	123	121	121
54	County-Other	Hays	136	132	129	127	126	126	126
55	Canyon Lake WSC	Comal	137	134	133	132	132	132	132
56	Lockhart	Caldwell	138	134	131	129	128	127	127
57	Oak Hills WSC	Wilson	138	133	130	128	127	127	127
58	Universal City	Bexar	140	135	132	129	127	126	126
59	Balcones Heights	Bexar	142	138	135	132	129	128	128
60	Schertz	Guadalupe	143	138	136	134	133	133	133
61	Sunko WSC	Wilson	143	138	135	132	131	130	130
62	Woodsboro	Refugio	144	140	137	134	131	130	130
63	Olmos Park	Bexar	145	141	138	135	132	131	131
64	Terrell Hills	Bexar	145	140	137	134	131	130	130
65	San Antonio	Bexar	147	143	139	137	135	134	134
66	Yoakum	Dewitt	147	144	141	138	135	133	133
67	Mountain City	Hays	148	143	141	140	139	139	139
68	County Line WSC	Hays	149	144	142	141	140	140	140
69	County-Other	Zavala	150	146	143	141	139	138	138
70	Poth	Wilson	152	148	144	141	139	138	138
71	San Marcos	Hays	152	147	143	141	139	138	138
72	Charlotte	Atascosa	154	150	147	144	141	140	140
73	Encinal	La Salle	156	153	150	147	143	142	142
74	Luling	Caldwell	156	151	148	145	142	141	141
75	Natalia	Medina	156	152	149	147	145	144	144
76	Point Comfort	Calhoun	160	157	154	151	148	146	146
77	County-Other	Karnes	161	158	157	156	155	155	155
78	Runge	Karnes	161	158	154	151	148	147	147
79	Falls City	Karnes	162	157	154	151	149	148	148
80	Seadrift	Calhoun	163	160	156	153	150	149	149
81	Goliad	Goliad	165	161	158	155	152	151	151
82	Victoria	Victoria	166	162	159	156	153	152	152
83	Yancey WSC	Medina	168	164	161	159	158	157	157
84	Boerne	Kendall	169	163	160	158	156	156	156
85	Cuero	Dewitt	169	166	163	160	157	155	155
86	El Oso WSC	Karnes	169	165	162	159	157	156	156

Continued on next page

Table 4C.1-3 Concluded

County Number	Water User Group*	County	Per Capita Water Use with Low Flow Plumbing Fixtures						
			2000 (gpcd)	2010 (gpcd)	2020 (gpcd)	2030 (gpcd)	2040 (gpcd)	2050 (gpcd)	2060 (gpcd)
87	Nixon	Gonzales	169	166	162	160	157	156	156
88	Refugio	Refugio	169	164	161	158	156	155	155
89	Springs Hill WSC	Guadalupe	172	168	164	162	160	159	159
90	County-Other	Caldwell	173	172	170	167	162	159	159
91	Lytle	Atascosa	174	171	167	164	161	160	160
92	Cibolo	Guadalupe	176	172	169	168	167	167	167
93	Helotes	Bexar	176	172	170	170	169	169	169
94	Jourdanton	Atascosa	177	173	169	166	164	163	163
95	Castle Hills	Bexar	178	174	171	168	165	163	163
96	Devine	Medina	179	175	172	168	165	164	164
97	Pearsall	Frio	179	176	173	170	166	165	165
98	Big Wells	Dimmit	180	176	173	170	167	166	166
99	Gonzales	Gonzales	181	177	174	171	169	168	168
100	Hondo	Medina	181	176	173	171	169	168	168
101	Seguin	Guadalupe	181	177	174	171	169	168	168
102	Asherton	Dimmit	182	177	174	171	168	167	167
103	Floresville	Wilson	183	179	175	172	170	169	169
104	Woodcreek Utilities Inc.	Hays	183	179	177	177	176	176	176
105	Somerset	Bexar	185	180	177	174	173	172	172
106	Kenedy	Karnes	194	190	186	183	180	179	179
107	Poteet	Atascosa	197	194	191	187	184	183	183
108	La Vernia	Wilson	198	194	191	189	187	187	187
109	Pleasanton	Atascosa	198	195	191	188	185	184	184
110	New Braunfels	Comal	204	200	196	194	193	192	192
111	Stockdale	Wilson	205	201	197	194	192	191	191
112	China Grove	Bexar	206	201	197	195	194	193	193
113	Castroville	Medina	208	204	200	197	195	194	194
114	Fairoaks Ranch	Bexar	209	207	206	205	204	203	203
115	Windcrest	Bexar	212	209	206	203	200	198	198
116	Garden Ridge	Comal	217	212	208	205	204	203	203
117	Mustang Ridge	Caldwell	222	217	213	211	210	209	209
118	Sabinal	Uvalde	232	229	226	223	220	218	218
119	Alamo Heights	Bexar	244	241	237	234	231	230	230
120	Dilley	Frio	253	250	247	244	243	242	242
121	Gonzales County WSC	Gonzales	264	260	256	254	252	251	251
122	Crystal City	Zavala	270	267	263	260	257	256	256
123	Carrizo Springs	Dimmit	275	271	268	265	262	261	261
124	Selma	Bexar	312	307	304	302	301	300	300
125	Cotulla	La Salle	314	310	307	304	301	300	300
126	Uvalde	Uvalde	363	359	356	353	350	348	348
127	Lackland AFB (CDP)	Bexar	393	389	386	383	380	378	378
128	Shavano Park	Bexar	408	405	402	398	395	394	394
129	Hollywood Park	Bexar	667	664	660	657	654	653	653
130	Hill Country Village	Bexar	731	728	725	722	719	717	717

* Some Water User Groups are located in more than one county and more than one river basin. The county in which the major part of the service area is located is named in this table. However, in later tables, water conservation estimates and costs are shown for service areas located in each county and river basin in which the WUG provides service.

In year 2000, in the South Central Texas Water Planning Region, 57 WUGs had per capita water use of less than 140 gpcd (Table 4C.1-4). WUGs with less than 140 gpcd represented 23.39 percent of the population of the Region in year 2000, and used 17.46 percent of the quantity of municipal water used in the Region in year 2000 (Table 4C.1-4). In 2000, 56.16 percent of the WUGs in the Region had per capita water use of 140 or more gpcd. This group represented 76.61 percent of the region's population in 2000, and accounted for 82.54 percent of the municipal water used in the Region in 2000 (Table 4C.1-4).

Table 4C.1-4.
Municipal Water User Groups
Number, Population and Water Use by Per Capita Water Use Levels
South Central Texas Water Planning Region

Per Capita Water Use in 2000 (gpcd)	*Number of WUGs*	*Percent of WUGs*	*Population*		*Water Use*	
			2000 (number)	*Percent of Total*	*2000 (acft)*	*Percent of Total*
Less than 140	57	43.84%	477,680	23.39%	59,372	17.46%
140 and Greater	73	56.16%	1,564,541	76.61%	280,651	82.54%
Totals	130	100.00%	2,042,221	100.00%	340,023	100.00%

For purposes of calculating the additional water conservation that needs to be included in the South Central Texas Regional Water Plan, for WUGS having projected needs, the projected per capita water use for municipal WUGs was calculated for the Region L municipal water conservation goals, as stated above, in comparison to the low flow plumbing fixtures per capita water use projections used in calculating municipal water demand (Table 4C.1-5). It is important to note that for the first few WUGs listed in Table 4C.1-5, the low flow plumbing fixtures had a greater effect than the Region L goal. For these WUGS, no additional water conservation is considered.

Additional plumbing fixtures water conservation potentials, in gpcd are shown in Table 4C.1-6 for each WUG of Region L, where the low flow plumbing fixtures effects that are already included in the water demand projections are deducted from the 18 gpcd plumbing fixtures potentials for municipal water demand reduction. In Table 4C.1-7, the per capita water conservation needed by each WUG to meet the Region L goals are tabulated for indoor (plumbing fixtures) and outdoor (lawn watering) water conservation.

Table 4C.1-5.
Municipal Water User Groups with Projected per Capita Water Use with Low Flow Pluming Fixtures and Region L Water Conservation Goals

No.	Water User Group *	County *	Year 2000 gpcd	Projected Per Capita Water Use with Low Flow Plumbing Fixtures *						Projected Per Capita Water Use with Region L Water Conservation Goals **					
				2010 gpcd	2020 gpcd	2030 gpcd	2040 gpcd	2050 gpcd	2060 gpcd	2010 gpcd	2020 gpcd	2030 gpcd	2040 gpcd	2050 gpcd	2060 gpcd
1	CALHOUN COUNTY WS	CALHOUN	71	66	64	62	61	60	60	69	68	66	64	63	61
2	COUNTY-OTHER	WILSON	81	78	76	75	74	74	74	79	77	75	73	71	70
3	GREEN VALLEY SUD	GUADALUPE	85	80	77	76	74	74	74	83	81	79	77	75	73
4	POLONIA WSC	CALDWELL	87	82	79	77	76	75	75	85	83	81	79	77	75
5	COUNTY-OTHER	VICTORIA	91	87	84	82	80	79	79	89	87	84	82	80	78
6	BENTON CITY WSC	ATASCOSA	94	90	88	87	86	86	86	92	89	87	85	83	81
7	COUNTY-OTHER	DIMMIT	96	93	90	87	84	83	83	94	91	89	87	85	83
8	COUNTY-OTHER	GOLIAD	98	94	92	89	87	86	86	96	93	91	89	86	84
9	CREEDMOOR-MAHA WSC	CALDWELL	98	94	90	88	87	86	86	96	93	91	89	86	84
10	GOFORTH WSC	HAYS	99	93	91	89	88	88	88	97	94	92	90	87	85
11	CRYSTAL CLEAR WSC	GUADALUPE	100	95	92	91	89	89	89	98	95	93	90	88	86
12	MARTINDALE	CALDWELL	100	97	93	90	87	86	86	98	95	93	90	88	86
13	PLUM CREEK WATER COMPANY	HAYS	100	95	92	90	89	89	89	98	95	93	90	88	86
14	COUNTY-OTHER	REFUGIO	101	99	96	93	89	87	87	99	96	94	91	89	87
15	MCCOY WSC	ATASCOSA	101	97	95	93	92	92	92	99	96	94	91	89	87
16	ATASCOSA RURAL WSC	BEXAR	102	96	93	91	90	89	89	99	97	95	92	90	88
17	COUNTY-OTHER	ATASCOSA	102	102	102	99	93	88	88	99	97	95	92	90	88
18	COUNTY-OTHER	KENDALL	102	96	94	92	91	91	91	99	97	95	92	90	88
19	WIMBERLEY WSC	HAYS	102	98	95	93	91	91	91	99	97	95	92	90	88
20	KIRBY	BEXAR	103	99	95	92	89	88	88	100	98	96	93	91	89
21	COUNTY-OTHER	DEWITT	105	102	99	96	93	91	91	102	100	97	95	93	90
22	COUNTY-OTHER	FRIO	105	101	97	95	93	92	92	102	100	97	95	93	90
23	KARNES CITY	KARNES	108	104	101	98	96	95	95	105	103	100	98	95	93
24	LEON VALLEY	BEXAR	108	105	102	99	96	94	94	105	103	100	98	95	93
25	MAXWELL WSC	CALDWELL	108	103	99	98	96	96	96	105	103	100	98	95	93
26	LIVE OAK	BEXAR	110	106	102	99	96	95	95	107	105	102	100	97	95
27	SS WSC	WILSON	110	104	102	100	99	99	99	107	105	102	100	97	95
28	COUNTY-OTHER	GONZALES	111	110	108	105	100	97	97	108	106	103	100	98	96
29	COUNTY-OTHER	GUADALUPE	112	110	107	104	100	98	98	109	107	104	101	99	96
30	SANTA CLARA	GUADALUPE	114	110	108	108	107	107	107	111	108	106	103	101	98
31	COUNTY-OTHER	BEXAR	115	113	111	109	107	106	106	112	109	107	104	101	99
32	EAST MEDINA SUD	MEDINA	115	111	108	106	104	103	103	112	109	107	104	101	99

Table 4C.1-5 (Continued)

No.	Water User Group *	County *	Year 2000 gpcd	Projected Per Capita Water Use with Low Flow Plumbing Fixtures * 2010 gpcd	2020 gpcd	2030 gpcd	2040 gpcd	2050 gpcd	2060 gpcd	Projected Per Capita Water Use with Region L Water Conservation Goals ** 2010 gpcd	2020 gpcd	2030 gpcd	2040 gpcd	2050 gpcd	2060 gpcd
33	CONVERSE	BEXAR	116	111	107	105	104	103	103	113	110	108	105	102	100
34	COUNTY-OTHER	COMAL	116	112	109	106	103	102	102	113	110	108	105	102	100
35	NIEDERWALD	HAYS	116	113	111	111	110	110	110	113	110	108	105	102	100
36	BEXAR MET WATER DISTRICT	BEXAR	118	114	111	108	105	104	104	115	112	109	107	104	102
37	KYLE	HAYS	118	114	113	112	111	111	111	115	112	109	107	104	102
38	BULVERDE CITY	COMAL	120	116	114	113	113	113	113	117	114	111	109	106	103
39	COUNTY-OTHER	UVALDE	122	118	115	113	112	111	111	119	116	113	110	108	105
40	EAST CENTRAL WSC	BEXAR	122	116	113	111	110	109	109	119	116	113	110	108	105
41	ST. HEDWIG	BEXAR	122	117	113	111	109	108	108	119	116	113	110	108	105
42	AQUA WSC	CALDWELL	123	118	115	112	111	110	110	120	117	114	111	109	106
43	PORT LAVACA	CALHOUN	123	120	117	114	111	110	110	120	117	114	111	109	106
44	MARION	GUADALUPE	125	121	118	115	113	112	112	122	119	116	113	110	108
45	WAELDER	GONZALES	125	122	119	116	115	114	114	122	119	116	113	110	108
46	COUNTY-OTHER	MEDINA	129	126	124	122	121	121	121	126	123	120	117	114	111
47	WATER SER INC (APEX)	BEXAR	129	124	121	119	118	117	117	126	123	120	117	114	111
48	WOODCREEK	HAYS	132	127	125	123	121	121	121	129	126	122	119	116	114
49	ELMENDORF	BEXAR	133	129	125	122	120	119	119	130	127	123	120	117	114
50	COUNTY-OTHER	LA SALLE	134	132	129	128	126	126	126	131	127	124	121	118	115
51	COUNTY-OTHER	CALHOUN	135	131	128	125	122	121	121	132	128	125	122	119	116
52	LACOSTE	MEDINA	135	131	127	125	122	121	121	132	128	125	122	119	116
53	YORKTOWN	DEWITT	135	132	129	126	123	121	121	132	128	125	122	119	116
54	COUNTY-OTHER	HAYS	136	132	129	127	126	126	126	133	129	126	123	120	117
55	CANYON LAKE WSC	COMAL	137	134	133	132	132	132	132	134	130	127	124	121	118
56	LOCKHART	CALDWELL	138	134	131	129	128	127	127	135	131	128	125	122	119
57	OAK HILLS WSC	WILSON	138	133	130	128	127	127	127	135	131	128	125	122	119
58	UNIVERSAL CITY	BEXAR	140	135	132	129	127	126	126	137	133	130	127	124	120
59	BALCONES HEIGHTS	BEXAR	142	138	135	132	129	128	128	137	134	130	127	124	121
60	SCHERTZ	GUADALUPE	143	138	136	134	133	133	133	137	134	131	127	124	121
61	SUNKO WSC	WILSON	143	138	135	132	131	130	130	137	134	131	127	124	121
62	WOODSBORO	REFUGIO	144	140	137	134	131	130	130	138	134	131	128	124	121
63	OLMOS PARK	BEXAR	145	141	138	135	132	131	131	138	134	131	128	125	122
64	TERRELL HILLS	BEXAR	145	140	137	134	131	130	130	138	134	131	128	125	122
65	SAN ANTONIO	BEXAR	147	143	139	137	135	134	134	138	135	131	128	125	122
66	YOAKUM	DEWITT	147	144	141	138	135	133	133	138	135	131	128	125	122
67	MOUNTAIN CITY	HAYS	148	143	141	140	139	139	139	138	135	132	128	125	122

Table 4C.1-5 (Continued)

No.	Water User Group *	County *	Year 2000 gpcd	Projected Per Capita Water Use with Low Flow Plumbing Fixtures *						Projected Per Capita Water Use with Region L Water Conservation Goals **					
				2010 gpcd	2020 gpcd	2030 gpcd	2040 gpcd	2050 gpcd	2060 gpcd	2010 gpcd	2020 gpcd	2030 gpcd	2040 gpcd	2050 gpcd	2060 gpcd
68	COUNTY LINE WSC	HAYS	149	144	142	141	140	140	140	139	135	132	129	125	122
69	COUNTY-OTHER	ZAVALA	150	146	143	141	139	138	138	139	135	132	129	126	123
70	POTH	WILSON	152	148	144	141	139	138	138	139	136	133	129	126	123
71	SAN MARCOS	HAYS	152	147	143	141	139	138	138	139	136	133	129	126	123
72	CHARLOTTE	ATASCOSA	154	150	147	144	141	140	140	140	136	133	130	126	123
73	ENCINAL	LA SALLE	156	153	150	147	143	142	142	141	137	133	130	127	124
74	LULING	CALDWELL	156	151	148	145	142	141	141	141	137	133	130	127	124
75	NATALIA	MEDINA	156	152	149	147	145	144	144	141	137	133	130	127	124
76	POINT COMFORT	CALHOUN	160	157	154	151	148	146	146	145	138	134	131	128	125
77	COUNTY-OTHER	KARNES	161	158	157	156	155	155	155	146	138	134	131	128	125
78	RUNGE	KARNES	161	158	154	151	148	147	147	146	138	134	131	128	125
79	FALLS CITY	KARNES	162	157	154	151	149	148	148	147	138	135	131	128	125
80	SEADRIFT	CALHOUN	163	160	156	153	150	149	149	147	138	135	132	128	125
81	GOLIAD	GOLIAD	165	161	158	155	152	151	151	149	139	135	132	129	126
82	VICTORIA	VICTORIA	166	162	159	156	153	152	152	150	139	136	132	129	126
83	YANCEY WSC	MEDINA	168	164	161	159	158	157	157	152	139	136	133	129	126
84	BOERNE	KENDALL	169	163	160	158	156	156	156	153	140	136	133	129	126
85	CUERO	DEWITT	169	166	163	160	157	155	155	153	140	136	133	129	126
86	EL OSO WSC	KARNES	169	165	162	159	157	156	156	153	140	136	133	129	126
87	NIXON	GONZALES	169	166	162	160	157	156	156	153	140	136	133	129	126
88	REFUGIO	REFUGIO	169	164	161	158	156	155	155	153	140	136	133	129	126
89	SPRINGS HILL WSC	GUADALUPE	172	168	164	162	160	159	159	156	141	137	133	130	127
90	COUNTY-OTHER	CALDWELL	173	172	170	167	162	159	159	156	141	137	134	130	127
91	LYTLE	ATASCOSA	174	171	167	164	161	160	160	157	142	137	134	130	127
92	CIBOLO	GUADALUPE	176	172	169	168	167	167	167	159	144	137	134	131	128
93	HELOTES	BEXAR	176	172	170	170	169	169	169	159	144	137	134	131	128
94	JOURDANTON	ATASCOSA	177	173	169	166	164	163	163	160	145	138	134	131	128
95	CASTLE HILLS	BEXAR	178	174	171	168	165	163	163	161	146	138	134	131	128
96	DEVINE	MEDINA	179	175	172	168	165	164	164	162	146	138	135	131	128
97	PEARSALL	FRIO	179	176	173	170	166	165	165	162	146	138	135	131	128
98	BIG WELLS	DIMMIT	180	176	173	170	167	166	166	163	147	138	135	132	128
99	GONZALES	GONZALES	181	177	174	171	169	168	168	164	148	138	135	132	128
100	HONDO	MEDINA	181	176	173	171	169	168	168	164	148	138	135	132	128
101	SEGUIN	GUADALUPE	181	177	174	171	169	168	168	164	148	138	135	132	128

Table 4C.1-5 (Concluded)

No.	Water User Group *	County *	Year 2000 gpcd	Projected Per Capita Water Use with Low Flow Plumbing Fixtures *						Projected Per Capita Water Use with Region L Water Conservation Goals **					
				2010 gpcd	2020 gpcd	2030 gpcd	2040 gpcd	2050 gpcd	2060 gpcd	2010 gpcd	2020 gpcd	2030 gpcd	2040 gpcd	2050 gpcd	2060 gpcd
102	ASHERTON	DIMMIT	182	177	174	171	168	167	167	165	149	139	135	132	129
103	FLORESVILLE	WILSON	183	179	175	172	170	169	169	166	150	139	135	132	129
104	WOODCREEK UTILITIES INC	HAYS	183	179	177	177	176	176	176	166	150	139	135	132	129
105	SOMERSET	BEXAR	185	180	177	174	173	172	172	167	151	139	136	132	129
106	KENEDY	KARNES	194	190	186	183	180	179	179	175	159	144	137	134	131
107	POTEET	ATASCOSA	197	194	191	187	184	183	183	178	161	146	138	134	131
108	LA VERNIA	WILSON	198	194	191	189	187	187	187	179	162	146	138	135	131
109	PLEASANTON	ATASCOSA	198	195	191	188	185	184	184	179	162	146	138	135	131
110	NEW BRAUNFELS	COMAL	204	200	196	194	193	192	192	184	167	151	139	136	132
111	STOCKDALE	WILSON	205	201	197	194	192	191	191	185	168	152	139	136	132
112	CHINA GROVE	BEXAR	206	201	197	195	194	193	193	186	168	152	139	136	133
113	CASTROVILLE	MEDINA	208	204	200	197	195	194	194	188	170	154	140	136	133
114	FAIROAKS RANCH	BEXAR	209	207	206	205	204	203	203	189	171	155	140	136	133
115	WINDCREST	BEXAR	212	209	206	203	200	198	198	192	173	157	142	137	134
116	GARDEN RIDGE	COMAL	217	212	208	205	204	203	203	196	177	161	145	138	134
117	MUSTANG RIDGE	CALDWELL	222	217	213	211	210	209	209	201	182	164	149	139	135
118	SABINAL	UVALDE	232	229	226	223	220	218	218	210	190	172	155	140	137
119	ALAMO HEIGHTS	BEXAR	244	241	237	234	231	230	230	221	200	180	163	148	138
120	DILLEY	FRIO	253	250	247	244	243	242	242	229	207	187	169	153	140
121	GONZALES COUNTY WSC	GONZALES	264	260	256	254	252	251	251	239	216	195	177	160	144
122	CRYSTAL CITY	ZAVALA	270	267	263	260	257	256	256	244	221	200	181	163	148
123	CARRIZO SPRINGS	DIMMIT	275	271	268	265	262	261	261	249	225	203	184	166	150
124	SELMA	BEXAR	312	307	304	302	301	300	300	282	255	231	209	189	171
125	COTULLA	LA SALLE	314	310	307	304	301	300	300	284	257	232	210	190	172
126	UVALDE	UVALDE	363	359	356	353	350	348	348	328	297	269	243	220	199
127	LACKLAND AFB (CDP)	BEXAR	393	389	386	383	380	378	378	355	321	291	263	238	215
128	SHAVANO PARK	BEXAR	408	405	402	398	395	394	394	369	334	302	273	247	223
129	HOLLYWOOD PARK	BEXAR	667	664	660	657	654	653	653	603	546	493	446	404	365
130	HILL COUNTRY VILLAGE	BEXAR	731	728	725	722	719	717	717	661	598	541	489	442	400

*Water Conservation Effects, as estimated by the TWDB and used in computing municipal water demand for municipal WUGs.

**Region L water conservation goals for municipal WUGs with water use of 140 gpcd and greater in year 2000 are to reduce per capita water use by 1 percent per year until the level of 140 gpcd is reached, after which the goal is to reduce per capita water use by one-fourth percent per year for the remainder of the planning period. For Municipal WUGs having per capita water use less than 140 gpcd in year 2000, the goal is to reduce per capita water use by one-fourth percent per year.

Table 4C.1-6.
Projected per Capita Water Conservation Potential with Low Flow Pumping Fixtures and Additional Plumbing Fixtures and Clothes Washers Retrofit

No.	Water User Group *	County *	Plumbing Fixtures Potentials gpcd	Low Flow Plumbing Fixtures Water Conservation Potentials *						Additional Plumbing Fixtures and Clothes Washer Conservation Potentials					
				2010 gpcd	2020 gpcd	2030 gpcd	2040 gpcd	2050 gpcd	2060 gpcd	2010 gpcd	2020 gpcd	2030 gpcd	2040 gpcd	2050 gpcd	2060 gpcd
1	CALHOUN COUNTY WS	CALHOUN	18	5	7	9	10	11	11	13	11	9	8	7	7
2	COUNTY-OTHER	WILSON	18	3	5	6	7	7	7	15	13	12	11	11	11
3	GREEN VALLEY SUD	GUADALUPE	18	5	8	9	11	11	11	13	10	9	7	7	7
4	POLONIA WSC	CALDWELL	18	5	8	10	11	12	12	13	10	8	7	6	6
5	COUNTY-OTHER	VICTORIA	18	4	7	9	11	12	12	14	11	9	7	6	6
6	BENTON CITY WSC	ATASCOSA	18	4	6	7	8	8	8	14	12	11	10	10	10
7	COUNTY-OTHER	DIMMIT	18	3	6	9	12	13	13	15	12	9	6	5	5
8	COUNTY-OTHER	GOLIAD	18	4	6	9	11	12	12	14	12	9	7	6	6
9	CREEDMOOR-MAHA WSC	CALDWELL	18	4	8	10	11	12	12	14	10	8	7	6	6
10	GOFORTH WSC	HAYS	18	6	8	10	11	11	11	12	10	8	7	7	7
11	CRYSTAL CLEAR WSC	GUADALUPE	18	5	8	9	11	11	11	13	10	9	7	7	7
12	MARTINDALE	CALDWELL	18	3	7	10	13	14	14	15	11	8	5	4	4
13	PLUM CREEK WATER COMPANY	HAYS	18	5	8	10	11	11	11	13	10	8	7	7	7
14	COUNTY-OTHER	REFUGIO	18	2	5	8	12	14	14	16	13	10	6	4	4
15	MCCOY WSC	ATASCOSA	18	4	6	8	9	9	9	14	12	10	9	9	9
16	ATASCOSA RURAL WSC	BEXAR	18	6	9	11	12	13	13	12	9	7	6	5	5
17	COUNTY-OTHER	ATASCOSA	18	0	0	3	9	14	14	18	18	15	9	4	4
18	COUNTY-OTHER	KENDALL	18	6	8	10	11	11	11	12	10	8	7	7	7
19	WIMBERLEY WSC	HAYS	18	4	7	9	11	11	11	14	11	9	7	7	7
20	KIRBY	BEXAR	18	4	8	11	14	15	15	14	10	7	4	3	3
21	COUNTY-OTHER	DEWITT	18	3	6	9	12	14	14	15	12	9	6	4	4
22	COUNTY-OTHER	FRIO	18	4	8	10	12	13	13	14	10	8	6	5	5
23	KARNES CITY	KARNES	18	4	7	10	12	13	13	14	11	8	6	5	5
24	LEON VALLEY	BEXAR	18	3	6	9	12	14	14	15	12	9	6	4	4
25	MAXWELL WSC	CALDWELL	18	5	9	10	12	12	12	13	9	8	6	6	6
26	LIVE OAK	BEXAR	18	4	8	11	14	15	15	14	10	7	4	3	3
27	SS WSC	WILSON	18	6	8	10	11	11	11	12	10	8	7	7	7
28	COUNTY-OTHER	GONZALES	18	1	3	6	11	14	14	17	15	12	7	4	4
29	COUNTY-OTHER	GUADALUPE	18	2	5	8	12	14	14	16	13	10	6	4	4
30	SANTA CLARA	GUADALUPE	18	4	6	6	7	7	7	14	12	12	11	11	11
31	COUNTY-OTHER	BEXAR	18	2	4	6	8	9	9	16	14	12	10	9	9
32	EAST MEDINA SUD	MEDINA	18	4	7	9	11	12	12	14	11	9	7	6	6
33	CONVERSE	BEXAR	18	5	9	11	12	13	13	13	9	7	6	5	5
34	COUNTY-OTHER	COMAL	18	4	7	10	13	14	14	14	11	8	5	4	4
35	NIEDERWALD	HAYS	18	3	5	5	6	6	6	15	13	13	12	12	12

Table 4C.1-6 (Continued)

No.	Water User Group *	County *	Plumbing Fixtures Potentials gpcd	Low Flow Plumbing Fixtures Water Conservation Potentials *						Additional Plumbing Fixtures and Clothes Washer Conservation Potentials					
				2010 gpcd	2020 gpcd	2030 gpcd	2040 gpcd	2050 gpcd	2060 gpcd	2010 gpcd	2020 gpcd	2030 gpcd	2040 gpcd	2050 gpcd	2060 gpcd
36	BEXAR MET WATER DISTRICT	BEXAR	18	4	7	10	13	14	14	14	11	8	5	4	4
37	KYLE	HAYS	18	4	5	6	7	7	7	14	13	12	11	11	11
38	BULVERDE CITY	COMAL	18	4	6	7	7	7	7	14	12	11	11	11	11
39	COUNTY-OTHER	UVALDE	18	4	7	9	10	11	11	14	11	9	8	7	7
40	EAST CENTRAL WSC	BEXAR	18	6	9	11	12	13	13	12	9	7	6	5	5
41	ST. HEDWIG	BEXAR	18	5	9	11	13	14	14	13	9	7	5	4	4
42	AQUA WSC	CALDWELL	18	5	8	11	12	13	13	13	10	7	6	5	5
43	PORT LAVACA	CALHOUN	18	3	6	9	12	13	13	15	12	9	6	5	5
44	MARION	GUADALUPE	18	4	7	10	12	13	13	14	11	8	6	5	5
45	WAELDER	GONZALES	18	3	6	9	10	11	11	15	12	9	8	7	7
46	COUNTY-OTHER	MEDINA	18	3	5	7	8	8	8	15	13	11	10	10	10
47	WATER SER INC (APEX)	BEXAR	18	5	8	10	11	12	12	13	10	8	7	6	6
48	WOODCREEK	HAYS	18	5	7	9	11	11	11	13	11	9	7	7	7
49	ELMENDORF	BEXAR	18	4	8	11	13	14	14	14	10	7	5	4	4
50	COUNTY-OTHER	LA SALLE	18	2	5	6	8	8	8	16	13	12	10	10	10
51	COUNTY-OTHER	CALHOUN	18	4	7	10	13	14	14	14	11	8	5	4	4
52	LACOSTE	MEDINA	18	4	8	10	13	14	14	14	10	8	5	4	4
53	YORKTOWN	DEWITT	18	3	6	9	12	14	14	15	12	9	6	4	4
54	COUNTY-OTHER	HAYS	18	4	7	9	10	10	10	14	11	9	8	8	8
55	CANYON LAKE WSC	COMAL	18	3	4	5	5	5	5	15	14	13	13	13	13
56	LOCKHART	CALDWELL	18	4	7	9	10	11	11	14	11	9	8	7	7
57	OAK HILLS WSC	WILSON	18	5	8	10	11	11	11	13	10	8	7	7	7
58	UNIVERSAL CITY	BEXAR	18	5	8	11	13	14	14	13	10	7	5	4	4
59	BALCONES HEIGHTS	BEXAR	18	4	7	10	13	14	14	14	11	8	5	4	4
60	SCHERTZ	GUADALUPE	18	5	7	9	10	10	10	13	11	9	8	8	8
61	SUNKO WSC	WILSON	18	5	8	11	12	13	13	13	10	7	6	5	5
62	WOODSBORO	REFUGIO	18	4	7	10	13	14	14	14	11	8	5	4	4
63	OLMOS PARK	BEXAR	18	4	7	10	13	14	14	14	11	8	5	4	4
64	TERRELL HILLS	BEXAR	18	5	8	11	14	15	15	13	10	7	4	3	3
65	SAN ANTONIO	BEXAR	18	5	8	11	14	15	15	13	10	7	4	3	3
66	YOAKUM	DEWITT	18	3	6	9	12	14	14	15	12	9	6	4	4
67	MOUNTAIN CITY	HAYS	18	5	7	8	9	9	9	13	11	10	9	9	9
68	COUNTY LINE WSC	HAYS	18	5	7	8	9	9	9	13	11	10	9	9	9
69	COUNTY-OTHER	ZAVALA	18	4	7	9	11	12	12	14	11	9	7	6	6
70	POTH	WILSON	18	4	8	11	13	14	14	14	10	7	5	4	4
71	SAN MARCOS	HAYS	18	5	9	11	13	14	14	13	9	7	5	4	4
72	CHARLOTTE	ATASCOSA	18	4	7	10	13	14	14	14	11	8	5	4	4
73	ENCINAL	LA SALLE	18	3	6	9	13	14	14	15	12	9	5	4	4
74	LULING	CALDWELL	18	5	8	11	14	15	15	13	10	7	4	3	3

Table 4C.1-6 (Continued)

No.	Water User Group *	County *	Plumbing Fixtures Potentials gpcd	Low Flow Plumbing Fixtures Water Conservation Potentials *						Additional Plumbing Fixtures and Clothes Washer Conservation Potentials					
				2010 gpcd	2020 gpcd	2030 gpcd	2040 gpcd	2050 gpcd	2060 gpcd	2010 gpcd	2020 gpcd	2030 gpcd	2040 gpcd	2050 gpcd	2060 gpcd
75	NATALIA	MEDINA	18	4	7	9	11	12	12	14	11	9	7	6	6
76	POINT COMFORT	CALHOUN	18	3	6	9	12	14	14	15	12	9	6	4	4
77	COUNTY-OTHER	KARNES	18	3	4	5	6	6	6	15	14	13	12	12	12
78	RUNGE	KARNES	18	3	7	10	13	14	14	15	11	8	5	4	4
79	FALLS CITY	KARNES	18	5	8	11	13	14	14	13	10	7	5	4	4
80	SEADRIFT	CALHOUN	18	3	7	10	13	14	14	15	11	8	5	4	4
81	GOLIAD	GOLIAD	18	4	7	10	13	14	14	14	11	8	5	4	4
82	VICTORIA	VICTORIA	18	4	7	10	13	14	14	14	11	8	5	4	4
83	YANCEY WSC	MEDINA	18	4	7	9	10	11	11	14	11	9	8	7	7
84	BOERNE	KENDALL	18	6	9	11	13	13	13	12	9	7	5	5	5
85	CUERO	DEWITT	18	3	6	9	12	14	14	15	12	9	6	4	4
86	EL OSO WSC	KARNES	18	4	7	10	12	13	13	14	11	8	6	5	5
87	NIXON	GONZALES	18	3	7	9	12	13	13	15	11	9	6	5	5
88	REFUGIO	REFUGIO	18	5	8	11	13	14	14	13	10	7	5	4	4
89	SPRINGS HILL WSC	GUADALUPE	18	4	8	10	12	13	13	14	10	8	6	5	5
90	COUNTY-OTHER	CALDWELL	18	1	3	6	11	14	14	17	15	12	7	4	4
91	LYTLE	ATASCOSA	18	3	7	10	13	14	14	15	11	8	5	4	4
92	CIBOLO	GUADALUPE	18	4	7	8	9	9	9	14	11	10	9	9	9
93	HELOTES	BEXAR	18	4	6	6	7	7	7	14	12	12	11	11	11
94	JOURDANTON	ATASCOSA	18	4	8	11	13	14	14	14	10	7	5	4	4
95	CASTLE HILLS	BEXAR	18	4	7	10	13	15	15	14	11	8	5	3	3
96	DEVINE	MEDINA	18	4	7	11	14	15	15	14	11	7	4	3	3
97	PEARSALL	FRIO	18	3	6	9	13	14	14	15	12	9	5	4	4
98	BIG WELLS	DIMMIT	18	4	7	10	13	14	14	14	11	8	5	4	4
99	GONZALES	GONZALES	18	4	7	10	12	13	13	14	11	8	6	5	5
100	HONDO	MEDINA	18	5	8	10	12	13	13	13	10	8	6	5	5
101	SEGUIN	GUADALUPE	18	4	7	10	12	13	13	14	11	8	6	5	5
102	ASHERTON	DIMMIT	18	5	8	11	14	15	15	13	10	7	4	3	3
103	FLORESVILLE	WILSON	18	4	8	11	13	14	14	14	10	7	5	4	4
104	WOODCREEK UTILITIES INC	HAYS	18	4	6	6	7	7	7	14	12	12	11	11	11
105	SOMERSET	BEXAR	18	5	8	11	12	13	13	13	10	7	6	5	5
106	KENEDY	KARNES	18	4	8	11	14	15	15	14	10	7	4	3	3
107	POTEET	ATASCOSA	18	3	6	10	13	14	14	15	12	8	5	4	4
108	LA VERNIA	WILSON	18	4	7	9	11	11	11	14	11	9	7	7	7
109	PLEASANTON	ATASCOSA	18	3	7	10	13	14	14	15	11	8	5	4	4
110	NEW BRAUNFELS	COMAL	18	4	8	10	11	12	12	14	10	8	7	6	6
111	STOCKDALE	WILSON	18	4	8	11	13	14	14	14	10	7	5	4	4
112	CHINA GROVE	BEXAR	18	5	9	11	12	13	13	13	9	7	6	5	5
113	CASTROVILLE	MEDINA	18	4	8	11	13	14	14	14	10	7	5	4	4

Table 4C.1-6 (Concluded)

No.	Water User Group *	County *	Plumbing Fixtures Potentials gpcd	Low Flow Plumbing Fixtures Water Conservation Potentials *						Additional Plumbing Fixtures and Clothes Washer Conservation Potentials					
				2010 gpcd	2020 gpcd	2030 gpcd	2040 gpcd	2050 gpcd	2060 gpcd	2010 gpcd	2020 gpcd	2030 gpcd	2040 gpcd	2050 gpcd	2060 gpcd
114	FAIROAKS RANCH	BEXAR	18	2	3	4	5	6	6	16	15	14	13	12	12
115	WINDCREST	BEXAR	18	3	6	9	12	14	14	15	12	9	6	4	4
116	GARDEN RIDGE	COMAL	18	5	9	12	13	14	14	13	9	6	5	4	4
117	MUSTANG RIDGE	CALDWELL	18	5	9	11	12	13	13	13	9	7	6	5	5
118	SABINAL	UVALDE	18	3	6	9	12	14	14	15	12	9	6	4	4
119	ALAMO HEIGHTS	BEXAR	18	3	7	10	13	14	14	15	11	8	5	4	4
120	DILLEY	FRIO	18	3	6	9	10	11	11	15	12	9	8	7	7
121	GONZALES COUNTY WSC	GONZALES	18	4	8	10	12	13	13	14	10	8	6	5	5
122	CRYSTAL CITY	ZAVALA	18	3	7	10	13	14	14	15	11	8	5	4	4
123	CARRIZO SPRINGS	DIMMIT	18	4	7	10	13	14	14	14	11	8	5	4	4
124	SELMA	BEXAR	18	5	8	10	11	12	12	13	10	8	7	6	6
125	COTULLA	LA SALLE	18	4	7	10	13	14	14	14	11	8	5	4	4
126	UVALDE	UVALDE	18	4	7	10	13	15	15	14	11	8	5	3	3
127	LACKLAND AFB (CDP)	BEXAR	18	4	7	10	13	15	15	14	11	8	5	3	3
128	SHAVANO PARK	BEXAR	18	3	6	10	13	14	14	15	12	8	5	4	4
129	HOLLYWOOD PARK	BEXAR	18	3	7	10	13	14	14	15	11	8	5	4	4
130	HILL COUNTRY VILLAGE	BEXAR	18	3	6	9	12	14	14	15	12	9	6	4	4

* Water Conservation Effects, as estimated by the Texas Water Development Board, and used in computing municipal water ddemand for municipal WUGS.

** Region L water conservation goals for municipal WUGs with water use of 140 gpcd and greater in year 2000 are to reduce per capita water use by one percent per year until the level of 140 gpcd is reached, after which the goal is to reduce per capita water use by one -fourth percent per year for the remainder of the planning period. For municipal WUGs having per capita water use less than 140 gpcd in year 2000, the goal is to reduce per capita water use by one -fourth

Table 4C.1-7.
Projected per Capita Water Conservation Potentials of Region L Municipal Water Conservation Goals with Additional Plumbing Fixturs and Clothes Washers Retrofit and Lawn Irrigation Water Conservation

			Additional Plumbing Fixtures and Clothes Washers Retrofit Conservation						Lawn Irrigation Water Conservation					
No.	**Water User Group ***	**County ***	**2010 gpcd**	**2020 gpcd**	**2030 gpcd**	**2040 gpcd**	**2050 gpcd**	**2060 gpcd**	**2010 gpcd**	**2020 gpcd**	**2030 gpcd**	**2040 gpcd**	**2050 gpcd**	**2060 gpcd**
1	CALHOUN COUNTY WS	CALHOUN	0	0	0	0	0	0	0	0	0	0	0	0
2	COUNTY-OTHER	WILSON	0	0	0	1	3	4	0	0	0	0	0	0
3	GREEN VALLEY SUD	GUADALUPE	0	0	0	0	0	1	0	0	0	0	0	0
4	POLONIA WSC	CALDWELL	0	0	0	0	0	0	0	0	0	0	0	0
5	COUNTY-OTHER	VICTORIA	0	0	0	0	0	1	0	0	0	0	0	0
6	BENTON CITY WSC	ATASCOSA	0	0	0	1	3	5	0	0	0	0	0	0
7	COUNTY-OTHER	DIMMIT	0	0	0	0	0	0	0	0	0	0	0	0
8	COUNTY-OTHER	GOLIAD	0	0	0	0	0	2	0	0	0	0	0	0
9	CREEDMOOR-MAHA WSC	CALDWELL	0	0	0	0	0	2	0	0	0	0	0	0
10	GOFORTH WSC	HAYS	0	0	0	0	1	3	0	0	0	0	0	0
11	CRYSTAL CLEAR WSC	GUADALUPE	0	0	0	0	1	3	0	0	0	0	0	0
12	MARTINDALE	CALDWELL	0	0	0	0	0	0	0	0	0	0	0	0
13	PLUM CREEK WATER COMPANY	HAYS	0	0	0	0	1	3	0	0	0	0	0	0
14	COUNTY-OTHER	REFUGIO	0	0	0	0	0	0	0	0	0	0	0	0
15	MCCOY WSC	ATASCOSA	0	0	0	1	3	5	0	0	0	0	0	0
16	ATASCOSA RURAL WSC	BEXAR	0	0	0	0	0	1	0	0	0	0	0	0
17	COUNTY-OTHER	ATASCOSA	3	5	4	1	0	0	0	0	0	0	0	0
18	COUNTY-OTHER	KENDALL	0	0	0	0	1	3	0	0	0	0	0	0
19	WIMBERLEY WSC	HAYS	0	0	0	0	1	3	0	0	0	0	0	0
20	KIRBY	BEXAR	0	0	0	0	0	0	0	0	0	0	0	0
21	COUNTY-OTHER	DEWITT	0	0	0	0	0	1	0	0	0	0	0	0
22	COUNTY-OTHER	FRIO	0	0	0	0	0	2	0	0	0	0	0	0
23	KARNES CITY	KARNES	0	0	0	0	0	2	0	0	0	0	0	0
24	LEON VALLEY	BEXAR	0	0	0	0	0	1	0	0	0	0	0	0
25	MAXWELL WSC	CALDWELL	0	0	0	0	1	3	0	0	0	0	0	0
26	LIVE OAK	BEXAR	0	0	0	0	0	0	0	0	0	0	0	0
27	SS WSC	WILSON	0	0	0	0	2	4	0	0	0	0	0	0
28	COUNTY-OTHER	GONZALES	2	2	2	0	0	1	0	0	0	0	0	0
29	COUNTY-OTHER	GUADALUPE	1	0	0	0	0	2	0	0	0	0	0	0
30	SANTA CLARA	GUADALUPE	0	0	2	4	6	9	0	0	0	0	0	0
31	COUNTY-OTHER	BEXAR	1	2	2	3	5	7	0	0	0	0	0	0
32	EAST MEDINA SUD	MEDINA	0	0	0	0	2	4	0	0	0	0	0	0
33	CONVERSE	BEXAR	0	0	0	0	1	3	0	0	0	0	0	0
34	COUNTY-OTHER	COMAL	0	0	0	0	0	2	0	0	0	0	0	0
35	NIEDERWALD	HAYS	0	1	3	5	8	10	0	0	0	0	0	0
36	BEXAR MET WATER DISTRICT	BEXAR	0	0	0	0	0	2	0	0	0	0	0	0

Table 4C.1-7 (Continued)

No.	Water User Group *	County *	Additional Plumbing Fixtures and Clothes Washers Retrofit Conservation						Lawn Irrigation Water Conservation					
			2010 gpcd	2020 gpcd	2030 gpcd	2040 gpcd	2050 gpcd	2060 gpcd	2010 gpcd	2020 gpcd	2030 gpcd	2040 gpcd	2050 gpcd	2060 gpcd
37	KYLE	HAYS	0	1	3	4	7	9	0	0	0	0	0	0
38	BULVERDE CITY	COMAL	0	0	2	4	7	10	0	0	0	0	0	0
39	COUNTY-OTHER	UVALDE	0	0	0	2	3	6	0	0	0	0	0	0
40	EAST CENTRAL WSC	BEXAR	0	0	0	0	1	4	0	0	0	0	0	0
41	ST. HEDWIG	BEXAR	0	0	0	0	0	3	0	0	0	0	0	0
42	AQUA WSC	CALDWELL	0	0	0	0	1	4	0	0	0	0	0	0
43	PORT LAVACA	CALHOUN	0	0	0	0	1	4	0	0	0	0	0	0
44	MARION	GUADALUPE	0	0	0	0	2	4	0	0	0	0	0	0
45	WAELDER	GONZALES	0	0	0	2	4	6	0	0	0	0	0	0
46	COUNTY-OTHER	MEDINA	0	1	2	4	7	10	0	0	0	0	0	0
47	WATER SER INC (APEX)	BEXAR	0	0	0	1	3	6	0	0	0	0	0	0
48	WOODCREEK	HAYS	0	0	1	2	5	7	0	0	0	0	0	0
49	ELMENDORF	BEXAR	0	0	0	0	2	5	0	0	0	0	0	0
50	COUNTY-OTHER	LA SALLE	1	2	4	5	8	11	0	0	0	0	0	0
51	COUNTY-OTHER	CALHOUN	0	0	0	0	2	5	0	0	0	0	0	0
52	LACOSTE	MEDINA	0	0	0	0	2	5	0	0	0	0	0	0
53	YORKTOWN	DEWITT	0	1	1	1	2	5	0	0	0	0	0	0
54	COUNTY-OTHER	HAYS	0	0	1	3	6	9	0	0	0	0	0	0
55	CANYON LAKE WSC	COMAL	0	3	5	8	11	13	0	0	0	0	0	1
56	LOCKHART	CALDWELL	0	0	1	3	5	7	0	0	0	0	0	1
57	OAK HILLS WSC	WILSON	0	0	0	2	5	7	0	0	0	0	0	1
58	UNIVERSAL CITY	BEXAR	0	0	0	0	2	4	0	0	0	0	0	2
59	BALCONES HEIGHTS	BEXAR	1	1	2	2	4	4	0	0	0	0	0	3
60	SCHERTZ	GUADALUPE	1	2	3	6	8	8	0	0	0	0	1	4
61	SUNKO WSC	WILSON	1	1	1	4	5	5	0	0	0	0	1	4
62	WOODSBORO	REFUGIO	2	3	3	3	4	4	0	0	0	0	2	5
63	OLMOS PARK	BEXAR	3	4	4	4	4	4	0	0	0	0	2	5
64	TERRELL HILLS	BEXAR	2	3	3	3	3	3	0	0	0	0	2	5
65	SAN ANTONIO	BEXAR	4	4	5	4	3	3	0	0	0	1	4	7
66	YOAKUM	DEWITT	6	6	7	6	4	4	0	0	0	1	4	7
67	MOUNTAIN CITY	HAYS	5	6	8	9	9	9	0	0	0	2	5	8
68	COUNTY LINE WSC	HAYS	5	7	9	9	9	9	0	0	0	2	6	9
69	COUNTY-OTHER	ZAVALA	7	8	9	7	6	6	0	0	0	3	6	9
70	POTH	WILSON	9	8	7	5	4	4	0	0	1	3	8	11
71	SAN MARCOS	HAYS	8	7	7	5	4	4	0	0	1	5	8	11
72	CHARLOTTE	ATASCOSA	10	11	8	5	4	4	0	0	3	6	10	13
73	ENCINAL	LA SALLE	12	12	9	5	4	4	0	1	5	8	11	14
74	LULING	CALDWELL	10	10	7	4	3	3	0	1	5	8	11	14
75	NATALIA	MEDINA	11	11	9	7	6	6	0	1	5	8	11	14

Table 4C.1-7 (Continued)

No.	Water User Group *	County *	Additional Plumbing Fixtures and Clothes Washers Retrofit Conservation 2010 gpcd	2020 gpcd	2030 gpcd	2040 gpcd	2050 gpcd	2060 gpcd	Lawn Irrigation Water Conservation 2010 gpcd	2020 gpcd	2030 gpcd	2040 gpcd	2050 gpcd	2060 gpcd
76	POINT COMFORT	CALHOUN	12	12	9	6	4	4	0	4	8	11	14	17
77	COUNTY-OTHER	KARNES	12	14	13	12	12	12	0	5	9	12	15	18
78	RUNGE	KARNES	12	11	8	5	4	4	0	5	9	12	15	18
79	FALLS CITY	KARNES	10	10	7	5	4	4	0	6	9	13	16	19
80	SEADRIFT	CALHOUN	13	11	8	5	4	4	0	7	10	13	17	20
81	GOLIAD	GOLIAD	12	11	8	5	4	4	0	8	12	15	18	21
82	VICTORIA	VICTORIA	12	11	8	5	4	4	0	9	12	16	19	22
83	YANCEY WSC	MEDINA	12	11	9	8	7	7	0	11	14	17	21	24
84	BOERNE	KENDALL	10	9	7	5	5	5	0	11	15	18	22	25
85	CUERO	DEWITT	13	12	9	6	4	4	0	11	15	18	22	25
86	EL OSO WSC	KARNES	12	11	8	6	5	5	0	11	15	18	22	25
87	NIXON	GONZALES	13	11	9	6	5	5	0	11	15	18	22	25
88	REFUGIO	REFUGIO	11	10	7	5	4	4	0	11	15	18	22	25
89	SPRINGS HILL WSC	GUADALUPE	12	10	8	6	5	5	0	13	17	21	24	27
90	COUNTY-OTHER	CALDWELL	16	15	12	7	4	4	0	14	18	21	25	28
91	LYTLE	ATASCOSA	14	11	8	5	4	4	0	14	19	22	26	29
92	CIBOLO	GUADALUPE	13	11	10	9	9	9	0	14	21	24	27	30
93	HELOTES	BEXAR	13	12	12	11	11	11	0	14	21	24	27	30
94	JOURDANTON	ATASCOSA	13	10	7	5	4	4	0	14	21	25	28	31
95	CASTLE HILLS	BEXAR	13	11	8	5	3	3	0	14	22	26	29	32
96	DEVINE	MEDINA	13	11	7	4	3	3	0	15	23	26	30	33
97	PEARSALL	FRIO	14	12	9	5	4	4	0	15	23	26	30	33
98	BIG WELLS	DIMMIT	13	11	8	5	4	4	0	15	24	27	30	34
99	GONZALES	GONZALES	13	11	8	6	5	5	0	15	25	28	31	35
100	HONDO	MEDINA	12	10	8	6	5	5	0	15	25	28	31	35
101	SEGUIN	GUADALUPE	13	11	8	6	5	5	0	15	25	28	31	35
102	ASHERTON	DIMMIT	12	10	7	4	3	3	0	15	25	29	32	35
103	FLORESVILLE	WILSON	13	10	7	5	4	4	0	15	26	30	33	36
104	WOODCREEK UTILITIES INC	HAYS	13	12	12	11	11	11	0	15	26	30	33	36
105	SOMERSET	BEXAR	13	10	7	6	5	5	0	16	28	31	35	38
106	KENEDY	KARNES	14	10	7	4	3	3	1	17	32	39	42	45
107	POTEET	ATASCOSA	15	12	8	5	4	4	1	18	33	41	45	48
108	LA VERNIA	WILSON	14	11	9	7	7	7	1	18	34	42	45	49
109	PLEASANTON	ATASCOS A	15	11	8	5	4	4	1	18	34	42	45	49
110	NEW BRAUNFELS	COMAL	14	10	8	7	6	6	2	19	35	47	50	54
111	STOCKDALE	WILSON	14	10	7	5	4	4	2	19	35	48	51	55
112	CHINA GROVE	BEXAR	13	9	7	6	5	5	2	20	36	49	52	55
113	CASTROVILLE	MEDINA	14	10	7	5	4	4	2	20	36	50	54	57
114	FAIROAKS RANCH	BEXAR	16	15	14	13	12	12	2	20	36	51	55	58

Table 4C.1-7 (Concluded)

No.	Water User Group *	County *	Additional Plumbing Fixtures and Clothes Washers Retrofit Conservation						Lawn Irrigation Water Conservation					
			2010 gpcd	2020 gpcd	2030 gpcd	2040 gpcd	2050 gpcd	2060 gpcd	2010 gpcd	2020 gpcd	2030 gpcd	2040 gpcd	2050 gpcd	2060 gpcd
115	WINDCREST	BEXAR	15	12	9	6	4	4	2	21	37	52	57	60
116	GARDEN RIDGE	COMAL	13	9	6	5	4	4	3	22	38	54	61	65
117	MUSTANG RIDGE	CALDWELL	13	9	7	6	5	5	3	22	40	55	65	69
118	SABINAL	UVALDE	15	12	9	6	4	4	4	24	42	59	74	77
119	ALAMO HEIGHTS	BEXAR	15	11	8	5	4	4	5	26	46	63	78	88
120	DILLEY	FRIO	15	12	9	8	7	7	6	28	48	66	82	95
121	GONZALES COUNTY WSC	GONZALES	14	10	8	6	5	5	7	30	51	69	86	102
122	CRYSTAL CITY	ZAVALA	15	11	8	5	4	4	8	31	52	71	89	104
123	CARRIZO SPRINGS	DIMMIT	14	11	8	5	4	4	8	32	54	73	91	107
124	SELMA	BEXAR	13	10	8	7	6	6	12	39	63	85	105	123
125	COTULLA	LA SALLE	14	11	8	5	4	4	12	39	64	86	106	124
126	UVALDE	UVALDE	14	11	8	5	3	3	17	48	76	102	125	146
127	LACKLAND AFB (CDP)	BEXAR	14	11	8	5	3	3	20	54	84	112	137	160
128	SHAVANO PARK	BEXAR	15	12	8	5	4	4	21	56	88	117	143	167
129	HOLLYWOOD PARK	BEXAR	15	11	8	5	4	4	46	103	156	203	245	284
130	HILL COUNTRY VILLAGE	BEXAR	15	12	9	6	4	4	52	115	172	224	271	313

* Water Conservation Effects, as estimated by the Texas Water Development Board, and used in computing municipal water ddemand for municipal WUGS.

** Region L water conservation goals for municipal WUGs with water use of 140 gpcd and greater in yea r 2000 are to reduce per capita water use by one percent per year until the level of 140 gpcd is reached, after which the goal is to reduce per capita water use by one-fourth percent per year for the remainder of the planning period. For municipal WUGs having per capita water use less than 140 gpcd in year 2000, the goal is to reduce per capita water use by one-fourth percent per year.

The water conservation water management strategy for Municipal Water User Groups (WUGs) of Region L is based upon BMPs listed above, and quantities and costs of water conservation measures, as reported in, "Quantifying the Effectiveness of Various Water Conservation Techniques in Texas, Texas Water Development Board, GDS Associates, Austin, Texas, July 2003," and the Water Conservation Implementation Task Force guidelines for water-use targets and goals listed above. The purpose of the municipal water conservation water management strategy is to evaluate the potentials of additional municipal water conservation for inclusion in the Regional Water Plan to meet a part of the projected water needs (shortages) of each WUG for which a need (shortage) is projected.

The calculations for the municipal water conservation water management strategy for municipal WUGs is presented below, and includes both indoor (plumbing fixtures and clothes washers) and outdoor (lawn watering and landscape irrigation) water conservation methods. The underlying methods and assumptions are as follows:

1. Indoor plumbing fixture water conservation potentials are 18 gpcd.. a part of which has already been included in the per capita water use projections shown in Table 4C.1-3, and is taken into account in the computations of quantities and costs of the municipal water conservation water management strategy;
2. Outdoor (lawn and landscape) water conservation is used to meet the projected conservation that is needed in order to meet the Region L municipal water goals, as stated above; and
3. Costs of municipal water conservation were obtained from a TWDB study, and are as follows:

    - Plumbing fixture and clothes washer retrofit (Table 4C.1-8)[6]
        - Rural areas………………………………...$588 per acre-foot;
        - Suburban areas…………………………….$520 per acre-foot; and
        - Urban areas………………………………..$458 per acre-foot.
    - Lawn watering and landscape water conservation… $400 per acre-foot.

The per capita municipal water conservation potentials for indoor (plumbing fixtures and clothes washers) and outdoor (lawn and landscape irrigation) are tabulated for each WUG of Region L in Table 4C.1-5, and are shown in 3 parts as follows:

1. Low flow plumbing fixtures water conservation potentials, as provided by TWDB for use in the municipal water demand projections.
2. Additional plumbing fixtures and clothes washer water conservation calculated at 1.0 % and 0.25 % per year respectively, as stated in the goals, above.
3. Lawn and landscape irrigation conservation potentials.

[6] GDS Associates, "Quantifying the Effectiveness of Various Water Conservation Techniques in Texas; Appendix VI, Region L," Texas Water Development Board, Austin, Texas, July 2003.

Table 4C.1-8.
Water Conservation Potentials and Costs of Various Water Conservation Techniques in Rural, Suburban, and Urban Residential Housing South Central Texas Water Planning Region

Water Conservation Techniques*	Life (Years)	Discount Factor at 6%	Potential Savings for Region L (acft)	Number of People Affected	Potential Savings (acft per person per year)	Total Costs (dollars)	Cost per acft of Water Saved Amortized at 6%*
Rural Areas							
SF Toilet Retrofit	25	0.0782	1,536	326,520	0.004705	9,389,823	478
SF Showerheads and Aerators	15	0.1029	805	326,520	0.002464	773,280	99
SF Clothes Washer Rebate	13	0.1129	1,843	326,520	0.005646	14,913,248	913
MF Toilet Retrofit	25	0.0782	65	11,083	0.005881	258,204	310
MF Showerheads and Aerators	15	0.1029	34	11,083	0.003080	13,771	42
MF Clothes Washer Rebate	8	0.1610	8	11,083	0.000754	29,837	575
Totals **			4,292	337,603	**0.012713**	25,378,161	**$ 588****
Suburban Areas							
SF Toilet Retrofit	25	0.0782	2,254	279,152	0.008075	12,323,999	428
SF Showerheads and Aerators	15	0.1029	1,181	279,152	0.004230	1,014,918	88
SF Clothes Washer Rebate	13	0.1129	2,705	279,152	0.009690	19,573,410	817
MF Toilet Retrofit	25	0.0782	222	37,787	0.005881	1,027,569	362
MF Showerheads and Aerators	15	0.1029	116	37,787	0.003080	54,804	48
MF Clothes Washer Rebate	8	0.1610	33	37,787	0.000880	118,741	575
Totals **			6,512	316,939	**0.020546**	34,113,440	**$ 520****
Urban Areas							
SF Toilet Retrofit	25	0.0782	4,406	936,489	0.004705	22,309,533	396
SF Showerheads and Aerators	15	0.1029	2,308	936,489	0.002464	1,837,256	82
SF Clothes Washer Rebate	13	0.1129	5,287	936,489	0.005646	35,432,787	757
MF Toilet Retrofit	25	0.0782	1,427	242,646	0.005881	6,427,999	352
MF Showerheads and Aerators	15	0.1029	747	242,646	0.003080	342,827	47
MF Clothes Washer Rebate	8	0.1610	208	242,646	0.000857	742,791	575
Totals **			14,383	1,179,135	**0.012198**	67,093,193	**$ 458****

* SF is Single Family and MF is Multi-family residential housing. Potentials for Water Conservation in Commercial Sector estimated at zero due to expected poor participation.

** Weighted average of measures included. Used to obtain cost per acre foot of municipal water conservation for use in calculating unit and total costs for water conservation water management strategy for Region L.

Source: "Quantifying the Effectiveness of Various Water Conservation Techniques in Texas," Texas Water Development Board, GDS Associates, Austin, Texas, July 2003.

The estimated quantities of water conservation potential (or water demand reduction) and associated costs for the WUGs of Region L for which additional water conservation is needed in order to reach the Region L water conservation goals are presented in Table 4C.1-9. The information shown in Table 4C.1-9 for each of the 73 WUGs for which water conservation estimates have been calculated is illustrated using the City of San Antonio (Number 65 on the list) as an example. For example, with additional water conservation through plumbing fixtures and clothes washers retrofit, the water conservation water management strategy would meet 5,752 acft/yr of projected need (shortages) in 2010; 8,795 acft/yr in 2030; and 7,113 acft/yr in 2060 (Table 4C.1-9). In order to meet the Region L water conservation goals, additional water conservation through lawn irrigation would provide 2,098 acft/yr in 2040; 8,970 acft/yr in 2050; and 16,598 acft/yr in 2060 (Table 4C.1-9).

Potential water conservation associated with implementation of the cited BMPs by each of the WUGs can be viewed in Table 4C.1-9. The projected water demand reductions shown in Table 4C.1-9 are the quantities for the water conservation water management strategy, and for WUGs with projected needs (shortages) will be included to meet a part the projected needs (shortages) of WUGs in the 2006 Regional Water Plan, respectively. Total projected water demand reduction through water conservation, needed to meet the Region L per capita water use goals is 13,231 acft/yr in 2010, 31,616 acft/yr in 2030, and 72,570 acft/yr in 2060 (Table 4C.1-10). The associated costs for the water conservation water management strategy are shown in Table 4C.1-7.

The estimated costs of municipal water conservation for each individual WUG are shown in Table 4C.1-11 for additional plumbing fixtures and clothes washers retrofit, Table 4C.1-12 for lawn irrigation, and Table 4C.1-13 for the total of plumbing fixtures and clothes washers retrofit and lawn irrigation. The costs depend upon quantity of water conservation potential, as well as location. For example, San Marcos (Number 71 on the list) has a potential of 417 acft/yr in 2010, with a cost $217,098, and a potential of 2,656 acft/yr in 2060 at a cost of $1,147,567 (Table 4C.1-10 and Table 4C.1-13, respectively). Total cost for implementation and administration of the municipal water conservation water management strategy to meet the Region L goals of reducing per capita water use at the 1 percent and 0.25 percent rates, as

Table 4C.1-9.
Projected Water Demand Reduction from Additional Plumbing Fixtures and Clothes Washers Retrofit and Lawn Irrigation Water Conservation

No.	Water User Group *	County *	Additional Plumbing Fixtures and Clothes Washers Retrofit Conservation						Lawn Irrigation Water Conservation					
			2010 acft/yr	2020 acft/yr	2030 acft/yr	2040 acft/yr	2050 acft/yr	2060 acft/yr	2010 acft/yr	2020 acft/yr	2030 acft/yr	2040 acft/yr	2050 acft/yr	2060 acft/yr
1	CALHOUN COUNTY WS	CALHOUN	0	0	0	0	0	0	0	0	0	0	0	0
2	COUNTY-OTHER	WILSON	0	0	0	14	58	116	0	0	0	0	0	0
3	GREEN VALLEY SUD	GUADALUPE	0	0	0	0	0	20	0	0	0	0	0	0
4	POLONIA WSC	CALDWELL	0	0	0	0	0	0	0	0	0	0	0	0
5	COUNTY-OTHER	VICTORIA	0	0	0	0	0	32	0	0	0	0	0	0
6	BENTON CITY WSC	ATASCOSA	0	0	0	24	85	153	0	0	0	0	0	0
7	COUNTY-OTHER	DIMMIT	0	0	0	0	0	0	0	0	0	0	0	0
8	COUNTY-OTHER	GOLIAD	0	0	0	0	0	16	0	0	0	0	0	0
9	CREEDMOOR-MAHA WSC	CALDWELL	0	0	0	0	0	11	0	0	0	0	0	0
10	GOFORTH WSC	HAYS	0	0	0	0	22	111	0	0	0	0	0	0
11	CRYSTAL CLEAR WSC	GUADALUPE	0	0	0	0	41	184	0	0	0	0	0	0
12	MARTINDALE	CALDWELL	0	0	0	0	0	0	0	0	0	0	0	0
13	PLUM CREEK WATER COMPANY	HAYS	0	0	0	0	12	54	0	0	0	0	0	0
14	COUNTY-OTHER	REFUGIO	0	0	0	0	0	0	0	0	0	0	0	0
15	MCCOY WSC	ATASCOSA	0	0	0	13	68	129	0	0	0	0	0	0
16	ATASCOSA RURAL WSC	BEXAR	0	0	0	0	0	22	0	0	0	0	0	0
17	COUNTY-OTHER	ATASCOSA	11	17	11	1	0	0	0	0	0	0	0	0
18	COUNTY-OTHER	KENDALL	0	0	0	0	73	264	0	0	0	0	0	0
19	WIMBERLEY WSC	HAYS	0	0	0	0	19	70	0	0	0	0	0	0
20	KIRBY	BEXAR	0	0	0	0	0	0	0	0	0	0	0	0
21	COUNTY-OTHER	DEWITT	0	0	0	0	0	6	0	0	0	0	0	0
22	COUNTY-OTHER	FRIO	0	0	0	0	0	18	0	0	0	0	0	0
23	KARNES CITY	KARNES	0	0	0	0	0	11	0	0	0	0	0	0
24	LEON VALLEY	BEXAR	0	0	0	0	0	12	0	0	0	0	0	0
25	MAXWELL WSC	CALDWELL	0	0	0	0	11	55	0	0	0	0	0	0
26	LIVE OAK	BEXAR	0	0	0	0	0	0	0	0	0	0	0	0
27	SS WSC	WILSON	0	0	0	0	84	221	0	0	0	0	0	0
28	COUNTY-OTHER	GONZALES	6	7	5	0	0	3	0	0	0	0	0	0
29	COUNTY-OTHER	GUADALUPE	2	0	0	0	0	0	0	0	0	0	0	0
30	SANTA CLARA	GUADALUPE	0	0	10	23	47	79	0	0	0	0	0	0
31	COUNTY-OTHER	BEXAR	49	96	140	191	310	505	0	0	0	0	0	0
32	EAST MEDINA SUD	MEDINA	0	0	0	0	19	54	0	0	0	0	0	0
33	CONVERSE	BEXAR	0	0	0	0	21	110	0	0	0	0	0	0
34	COUNTY-OTHER	COMAL	0	0	0	0	0	85	0	0	0	0	0	0
35	NIEDERWALD	HAYS	0	1	8	15	27	42	0	0	0	0	0	0
36	BEXAR MET WATER DISTRICT	BEXAR	0	0	0	0	0	293	0	0	0	0	0	0

Table 4C.1-9 (Continued)

37	KYLE	HAYS	0	27	96	167	302	443	0	0	0	0	0	0
38	BULVERDE CITY	COMAL	0	0	38	130	260	430	0	0	0	0	0	0
39	COUNTY-OTHER	UVALDE	0	0	0	33	73	137	0	0	0	0	0	0
40	EAST CENTRAL WSC	BEXAR	0	0	0	0	32	104	0	0	0	0	0	0
41	ST. HEDWIG	BEXAR	0	0	0	0	0	14	0	0	0	0	0	0
42	AQUA WSC	CALDWELL	0	0	0	0	6	19	0	0	0	0	0	0
43	PORT LAVACA	CALHOUN	0	0	0	0	30	89	0	0	0	0	0	0
44	MARION	GUADALUPE	0	0	0	0	3	10	0	0	0	0	0	0
45	WAELDER	GONZALES	0	0	0	3	7	11	0	0	0	0	0	0
46	COUNTY-OTHER	MEDINA	0	20	41	86	160	244	0	0	0	0	0	0
47	WATER SER INC (APE X)	BEXAR	0	0	0	18	50	105	0	0	0	0	0	0
48	WOODCREEK	HAYS	0	0	2	6	20	37	0	0	0	0	0	0
49	ELMENDORF	BEXAR	0	0	0	0	2	6	0	0	0	0	0	0
50	COUNTY-OTHER	LA SALLE	3	4	11	17	29	42	0	0	0	0	0	0
51	COUNTY-OTHER	CALHOUN	0	0	0	0	4	11	0	0	0	0	0	0
52	LACOSTE	MEDINA	0	0	0	0	4	11	0	0	0	0	0	0
53	YORKTOWN	DEWITT	0	2	2	2	5	13	0	0	0	0	0	0
54	COUNTY-OTHER	HAYS	0	0	12	49	112	184	0	0	0	0	0	0
55	CANYON LAKE WSC	COMAL	0	96	254	543	929	1,313	0	0	0	0	0	101
56	LOCKHART	CALDWELL	0	0	28	103	195	291	0	0	0	0	0	42
57	OAK HILLS WSC	WILSON	0	0	0	26	76	119	0	0	0	0	0	17
58	UNIVERSAL CITY	BEXAR	0	0	0	0	49	98	0	0	0	0	0	49
59	BALCONES HEIGHTS	BEXAR	4	6	7	9	20	21	0	0	0	0	0	16
60	SCHERTZ	GUADALUPE	22	87	182	365	617	725	0	0	0	0	77	363
61	SUNKO WSC	WILSON	3	6	10	29	45	51	0	0	0	0	9	41
62	WOODSBORO	REFUGIO	5	6	7	8	9	9	0	0	0	0	5	11
63	OLMOS PARK	BEXAR	9	11	13	14	14	15	0	0	0	0	7	18
64	TERRELL HILLS	BEXAR	14	18	21	24	24	24	0	0	0	0	16	41
65	SAN ANTONIO	BEXAR	5,752	7,318	8,795	8,392	6,728	7,113	0	0	0	2,098	8,970	16,598
66	YOAKUM	DEWITT	14	16	17	15	10	10	0	0	0	3	10	17
67	MOUNTAIN CITY	HAYS	1	3	6	8	10	12	0	0	0	2	6	11
68	COUNTY LINE WSC	HAYS	43	110	176	186	206	236	0	0	0	41	138	236
69	COUNTY-OTHER	ZAVALA	42	54	71	62	58	60	0	0	0	27	58	89
70	POTH	WILSON	20	22	22	17	15	17	0	0	3	10	31	47
71	SAN MARCOS	HAYS	417	554	713	641	625	708	0	0	102	641	1,250	1,948
72	CHARLOTTE	ATASCOSA	20	23	18	12	10	10	0	0	7	14	24	33
73	ENCINAL	LA SALLE	9	9	7	4	3	3	0	1	4	6	8	11
74	LULING	CALDWELL	70	82	63	39	32	34	0	8	45	78	116	158
75	NATALIA	MEDINA	24	28	25	22	20	22	0	3	13	24	37	51
76	POINT COMFORT	CALHOUN	18	25	30	27	18	18	0	9	26	51	65	80
77	COUNTY-OTHER	KARNES	68	88	95	97	101	102	0	32	62	96	127	156
78	RUNGE	KARNES	15	15	12	8	6	7	0	7	12	18	24	31
79	FALLS CITY	KARNES	8	8	6	5	4	4	0	5	8	12	15	19

Table 4C.1-9 (Continued)

80	SEADRIFT	CALHOUN	20	18	13	9	7	7	0	11	17	23	29	34
81	GOLIAD	GOLIAD	30	33	27	18	15	16	0	25	40	55	70	85
82	VICTORIA	VICTORIA	874	876	676	442	367	378	0	722	1,056	1,402	1,752	2,107
83	YANCEY WSC	MEDINA	61	69	67	67	65	71	0	67	105	147	194	244
84	BOERNE	KENDALL	98	123	126	108	123	137	0	156	268	394	529	679
85	CUERO	DEWITT	99	93	70	47	31	30	0	88	116	143	167	188
86	EL OSO WSC	KARNES	41	41	32	26	23	23	0	42	60	79	97	115
87	NIXON	GONZALES	35	31	27	19	16	16	0	32	45	57	68	77
88	REFUGIO	REFUGIO	44	44	32	24	20	20	0	50	68	89	109	124
89	SPRINGS HILL WSC	GUADALUPE	174	163	151	128	121	136	0	218	326	442	580	740
90	COUNTY-OTHER	CALDWELL	21	20	14	8	4	4	0	18	22	23	24	25
91	LYTLE	ATASCOSA	38	32	24	16	13	13	0	40	58	70	83	95
92	CIBOLO	GUADALUPE	65	77	92	102	124	147	0	99	189	272	375	498
93	HELOTES	BEXAR	115	159	199	212	239	263	0	186	340	462	593	729
94	JOURDANTON	ATASCOSA	60	51	39	29	24	25	0	73	117	144	171	197
95	CASTLE HILLS	BEXAR	61	52	38	24	14	14	0	68	104	121	136	152
96	DEVINE	MEDINA	63	54	36	21	16	16	0	72	117	138	159	180
97	PEARSALL	FRIO	116	100	77	43	35	35	0	122	195	228	259	289
98	BIG WELLS	DIMMIT	11	10	8	5	4	4	0	13	22	26	28	30
99	GONZALES	GONZALES	116	104	80	62	53	52	0	141	245	291	329	362
100	HONDO	MEDINA	125	116	103	84	76	81	0	173	317	393	475	559
101	SEGUIN	GUADALUPE	377	362	302	256	240	269	0	492	927	1,192	1,504	1,861
102	ASHERTON	DIMMIT	20	17	13	7	5	5	0	26	45	52	56	59
103	FLORESVILLE	WILSON	136	115	91	73	65	71	0	176	342	431	532	643
104	WOODCREEK UTILITIES INC	HAYS	56	78	106	123	155	180	0	99	231	332	464	591
105	SOMERSET	BEXAR	29	27	22	21	19	21	0	43	88	110	133	156
106	KENEDY	KARNES	56	44	33	20	16	17	2	77	155	196	226	251
107	POTEET	ATASCOSA	57	47	32	20	16	16	3	69	132	165	181	197
108	LA VERNIA	WILSON	20	21	22	21	25	29	1	35	82	125	160	199
109	PLEASANTON	ATASC OSA	147	113	86	56	46	47	9	186	362	467	520	569
110	NEW BRAUNFELS	COMAL	736	674	674	706	708	820	79	1,291	2,958	4,727	5,941	7,332
111	STOCKDALE	WILSON	24	20	15	12	11	12	3	38	78	116	137	159
112	CHINA GROVE	BEXAR	24	21	19	18	17	18	3	45	97	148	174	199
113	CASTROVILLE	MEDINA	47	37	29	22	19	20	6	74	147	220	251	282
114	FAIROAKS RANCH	BEXAR	111	105	99	93	87	87	14	141	258	366	394	422
115	WINDCREST	BEXAR	86	70	53	35	24	24	13	120	217	307	338	361
116	GARDEN RIDGE	COMAL	35	30	25	25	23	27	7	73	161	269	356	433
117	MUSTANG RIDGE	CALDWELL	8	8	7	7	7	8	2	19	41	67	91	108
118	SABINAL	UVALDE	27	21	16	11	7	7	7	43	76	105	131	138
119	ALAMO HEIGHTS	BEXAR	129	99	73	46	37	38	46	238	415	579	731	827
120	DILLEY	FRIO	74	68	57	55	51	53	30	160	305	455	601	719
121	GONZALES COUNTY WSC	GONZALES	94	78	69	55	47	47	49	234	436	638	811	955

Table 4C.1-9 (Concluded)

122	CRYSTAL CITY	ZAVALA	126	95	72	45	37	37	66	269	471	649	813	965
123	CARRIZO SPRINGS	DIMMIT	95	80	60	38	30	28	56	233	404	552	670	749
124	SELMA	BEXAR	71	70	69	61	52	52	64	274	547	740	914	1,070
125	COTULLA	LA SALLE	64	54	41	27	22	23	55	193	328	461	593	722
126	UVALDE	UVALDE	237	189	139	88	53	53	283	827	1,331	1,794	2,216	2,599
127	LACKLAND AFB (CDP)	BEXAR	112	88	64	40	24	24	156	427	673	894	1,095	1,276
128	SHAVANO PARK	BEXAR	30	25	17	11	9	9	43	117	188	254	315	373
129	HOLLYWOOD PARK	BEXAR	52	40	30	19	16	16	160	375	582	779	964	1,138
130	HILL COUNTRY VILLAGE	BEXAR	17	14	10	7	5	5	60	133	198	258	312	360
	Total		12,013	13,734	15,231	14,961	15,083	19,163	1,218	9,008	16,386	25,567	38,842	53,407

Table 4C.1-10. Projected Municipal Water Demand Reduction from Additional Plumbing Fixtures and Clothes Washers Retrofit and Lawn Irrigation Water Conservation (Totals) South Central Texas Water Planning Region

County Number	Water User Group*	County	Plumbing Fixtures and Clothes Washers Retrofit Plus Lawn Irrigation Conservation 2010 (acft/yr)	2020 (acft/yr)	2030 (acft/yr)	2040 (acft/yr)	2050 (acft/yr)	2060 (acft/yr)
1	Calhoun County WS	Calhoun	0	0	0	0	0	0
2	County-Other	Wilson	0	0	0	14	58	116
3	Green Valley SUD	Guadalupe	0	0	0	0	0	20
4	Polonia WSC	Caldwell	0	0	0	0	0	0
5	County-Other	Victoria	0	0	0	0	0	32
6	Benton City WSC	Atascosa	0	0	0	24	85	153
7	County-Other	Dimmit	0	0	0	0	0	0
8	County-Other	Goliad	0	0	0	0	0	16
9	Creedmoor-Maha WSC	Caldwell	0	0	0	0	0	11
10	Goforth WSC	Caldwell	0	0	0	0	22	111
11	Crystal Clear WSC	Guadalupe	0	0	0	0	41	184
12	Martindale	Caldwell	0	0	0	0	0	0
13	Plum Creek Water Co.	Hays	0	0	0	0	12	54
14	County-Other	Refugio	0	0	0	0	0	0
15	McCoy WSC	Atascosa	0	0	0	13	68	129
16	Atascosa Rural WSC	Bexar	0	0	0	0	0	22
17	County-Other	Atascosa	11	17	11	1	0	0
18	County-Other	Kendall	0	0	0	0	73	264
19	Wimberley WSC	Hays	0	0	0	0	19	70
20	Kirby	Bexar	0	0	0	0	0	0
21	County-Other	Dewitt	0	0	0	0	0	6
22	County-Other	Frio	0	0	0	0	0	18
23	Karnes City	Karnes	0	0	0	0	0	11
24	Leon Valley	Bexar	0	0	0	0	0	12
25	Maxwell WSC	Caldwell	0	0	0	0	11	55
26	Live Oak	Bexar	0	0	0	0	0	0
27	Ss WSC	Wilson	0	0	0	0	84	221
28	County-Other	Gonzales	6	7	5	0	0	3
29	County-Other	Guadalupe	2	0	0	0	0	0
30	Santa Clara	Guadalupe	0	0	10	23	47	79
31	County-Other	Bexar	49	96	140	191	310	505
32	East Medina SUD	Medina	0	0	0	0	19	54
33	Converse	Bexar	0	0	0	0	21	110
34	County-Other	Comal	0	0	0	0	0	85
35	Niederwald	Hays	0	1	8	15	27	42
36	Bexar Met Water District	Bexar	0	0	0	0	0	293
37	Kyle	Hays	0	27	96	167	302	443
38	Bulverde City	Comal	0	0	38	130	260	430
39	County-Other	Uvalde	0	0	0	33	73	137
40	East Central WSC	Bexar	0	0	0	0	32	104
41	St. Hedwig	Bexar	0	0	0	0	0	14
42	Aqua WSC	Caldwell	0	0	0	0	6	19

Table 4C-1-10 Continued

County Number	Water User Group*	County	Plumbing Fixtures and Clothes Washers Retrofit Plus Lawn Irrigation Conservation 2010 (acft/yr)	2020 (acft/yr)	2030 (acft/yr)	2040 (acft/yr)	2050 (acft/yr)	2060 (acft/yr)
43	Port Lavaca	Calhoun	0	0	0	0	30	89
44	Marion	Guadalupe	0	0	0	0	3	10
45	Waelder	Gonzales	0	0	0	3	7	11
46	County-Other	Medina	0	20	41	86	160	244
47	Water Ser Inc (APEX)	Bexar	0	0	0	18	50	105
48	Woodcreek	Hays	0	0	2	6	20	37
49	Elmendorf	Bexar	0	0	0	0	2	6
50	County-Other	La Salle	3	4	11	17	29	42
51	County-Other	Calhoun	0	0	0	0	4	11
52	Lacoste	Medina	0	0	0	0	4	11
53	Yorktown	Dewitt	0	2	2	2	5	13
54	County-Other	Hays	0	0	12	49	112	184
55	Canyon Lake WSC	Comal	0	96	254	543	929	1,414
56	Lockhart	Caldwell	0	0	28	103	195	333
57	Oak Hills WSC	Wilson	0	0	0	26	76	136
58	Universal City	Bexar	0	0	0	0	49	148
59	Balcones Heights	Bexar	4	6	7	9	20	37
60	Schertz	Guadalupe	22	87	182	365	694	1,088
61	Sunko WSC	Wilson	3	6	10	29	54	92
62	Woodsboro	Refugio	5	6	7	8	14	20
63	Olmos Park	Bexar	9	11	13	14	21	33
64	Terrell Hills	Bexar	14	18	21	24	39	65
65	San Antonio	Bexar	5,752	7,318	8,795	10,490	15,698	23,711
66	Yoakum	Dewitt	14	16	17	18	20	27
67	Mountain City	Hays	1	3	6	10	16	22
68	County Line WSC	Hays	43	110	176	227	344	473
69	County-Other	Zavala	42	54	71	89	115	149
70	Poth	Wilson	20	22	25	28	46	64
71	San Marcos	Hays	417	554	815	1,282	1,875	2,656
72	Charlotte	Atascosa	20	23	25	26	34	43
73	Encinal	La Salle	9	9	10	10	11	14
74	Luling	Caldwell	70	90	108	117	148	192
75	Natalia	Medina	24	31	38	46	58	73
76	Point Comfort	Calhoun	18	34	55	78	84	98
77	County-Other	Karnes	68	121	157	193	227	258
78	Runge	Karnes	15	22	24	26	31	37
79	Falls City	Karnes	8	13	14	16	19	23
80	Seadrift	Calhoun	20	29	30	32	36	41
81	Goliad	Goliad	30	59	67	73	85	100
82	Victoria	Victoria	874	1,597	1,733	1,844	2,118	2,485
83	Yancey WSC	Medina	61	136	171	214	259	316
84	Boerne	Kendall	98	280	394	502	652	816
85	Cuero	Dewitt	99	181	187	190	197	218
86	El Oso WSC	Karnes	41	83	92	105	120	139
87	Nixon	Gonzales	35	64	72	75	83	93

Table 4C-1-10 Concluded

County Number	Water User Group*	County	Plumbing Fixtures and Clothes Washers Retrofit Plus Lawn Irrigation Conservation 2010 (acft/yr)	2020 (acft/yr)	2030 (acft/yr)	2040 (acft/yr)	2050 (acft/yr)	2060 (acft/yr)
88	Refugio	Refugio	44	94	100	114	130	144
89	Springs Hill WSC	Guadalupe	174	381	477	571	701	877
90	County-Other	Caldwell	21	37	36	31	28	29
91	Lytle	Atascosa	38	72	82	86	96	108
92	Cibolo	Guadalupe	65	176	281	374	499	645
93	Helotes	Bexar	115	345	539	674	832	993
94	Jourdanton	Atascosa	60	123	156	173	195	222
95	Castle Hills	Bexar	61	120	142	144	151	166
96	Devine	Medina	63	127	152	159	175	196
97	Pearsall	Frio	116	223	272	271	294	324
98	Big Wells	Dimmit	11	23	30	30	32	33
99	Gonzales	Gonzales	116	245	325	353	381	414
100	Hondo	Medina	125	289	420	477	551	640
101	Seguin	Guadalupe	377	853	1,229	1,448	1,744	2,131
102	Asherton	Dimmit	20	43	58	59	62	64
103	Floresville	Wilson	136	291	433	504	596	714
104	Woodcreek Utilities Inc	Hays	56	177	337	455	619	771
105	Somerset	Bexar	29	70	110	131	152	177
106	Kenedy	Karnes	58	121	189	216	242	268
107	Poteet	Atascosa	60	116	163	185	198	213
108	La Vernia	Wilson	21	56	105	146	184	227
109	Pleasanton	Atascosa	156	300	448	523	565	615
110	New Braunfels	Comal	815	1,965	3,632	5,433	6,650	8,152
111	Stockdale	Wilson	27	57	93	128	147	171
112	China Grove	Bexar	28	66	116	166	190	217
113	Castroville	Medina	53	111	176	242	270	302
114	Fairoaks Ranch	Bexar	125	246	358	460	481	509
115	Windcrest	Bexar	99	189	270	343	362	385
116	Garden Ridge	Comal	42	103	187	294	379	460
117	Mustang Ridge	Caldwell	10	26	48	74	98	116
118	Sabinal	Uvalde	34	65	92	116	139	145
119	Alamo Heights	Bexar	175	337	488	625	769	865
120	Dilley	Frio	104	229	362	511	652	772
121	Gonzales County WSC	Gonzales	143	312	505	693	858	1,002
122	Crystal City	Zavala	192	364	543	695	850	1,002
123	Carrizo Springs	Dimmit	152	312	464	590	700	777
124	Selma	Bexar	135	344	617	801	966	1,122
125	Cotulla	La Salle	118	248	369	488	615	745
126	Uvalde	Uvalde	521	1,017	1,471	1,882	2,269	2,652
127	Lackland AFB (CDP)	Bexar	268	515	736	934	1,119	1,300
128	Shavano Park	Bexar	73	142	205	265	324	382
129	Hollywood Park	Bexar	212	414	612	798	980	1,154
130	Hill Country Village	Bexar	77	146	209	265	316	365
	Total		13,231	22,742	31,616	40,528	53,925	72,570

Table 4C.1-11.
Estimated Costs for Projected Municipal Water Conservation from Additional Plumbing Fixtures and Clothes Washers Retrofit
South Central Texas Water Planning Region

County Number	Water User Group*	County	Area	Cost per Acre-foot	Costs of Water Demand Reduction from Plumbing Fixtures and Clothes Washers Retrofit Conservation					
					2010 (dollars)	2020 (dollars)	2030 (dollars)	2040 (dollars)	2050 (dollars)	2060 (dollars)
1	Calhoun County WS	Calhoun	Rural	588	0	0	0	0	0	0
2	County-Other	Wilson	Rural	588	0	0	0	8,050	34,243	68,476
3	Green Valley SUD	Guadalupe	Rural	588	0	0	0	0	0	11,992
4	Polonia WSC	Caldwell	Rural	588	0	0	0	0	0	0
5	County-Other	Victoria	Rural	588	0	0	0	0	0	18,878
6	Benton City WSC	Atascosa	Rural	588	0	0	0	13,964	49,748	89,732
7	County-Other	Dimmit	Rural	588	0	0	0	0	0	0
8	County-Other	Goliad	Rural	588	0	0	0	0	0	9,670
9	Creedmoor-Maha WSC	Caldwell	Rural	588	0	0	0	0	0	6,644
10	Goforth WSC	Hays	Rural	588	0	0	0	0	13,133	65,352
11	Crystal Clear WSC	Guadalupe	Rural	588	0	0	0	0	24,036	108,003
12	Martindale	Caldwell	Rural	588	0	0	0	0	0	0
13	Plum Creek Water Co.	Hays	Rural	588	0	0	0	0	7,201	31,722
14	County-Other	Refugio	Rural	588	0	0	0	0	0	0
15	McCoy WSC	Atascosa	Rural	588	0	0	0	7,775	39,895	75,669
16	Atascosa Rural WSC	Bexar	Rural	588	0	0	0	0	0	13,044
17	County-Other	Atascosa	Rural	588	6,532	9,779	6,515	810	0	0
18	County-Other	Kendall	Rural	588	0	0	0	0	43,086	155,415
19	Wimberley WSC	Hays	Rural	588	0	0	0	0	11,207	40,963
20	Kirby	Bexar	Rural	588	0	0	0	0	0	0
21	County-Other	Dewitt	Rural	588	0	0	0	0	0	3,789
22	County-Other	Frio	Rural	588	0	0	0	0	0	10,572
23	Karnes City	Karnes	Rural	588	0	0	0	0	0	6,532
24	Leon Valley	Bexar	Suburban	520	0	0	0	0	0	6,079
25	Maxwell WSC	Caldwell	Rural	588	0	0	0	0	6,567	32,475
26	Live Oak	Bexar	Suburban	520	0	0	0	0	0	0
27	Ss WSC	Wilson	Rural	588	0	0	0	0	49,321	129,665
28	County-Other	Gonzales	Rural	588	3,659	4,216	2,986	0	0	1,831
29	County-Other	Guadalupe	Rural	588	1,107	0	0	0	0	124
30	Santa Clara	Guadalupe	Rural	588	0	0	6,015	13,335	27,662	46,643
31	County-Other	Bexar	Rural	588	28,834	56,217	82,441	112,410	182,263	297,122
32	East Medina SUD	Medina	Rural	588	0	0	0	0	11,266	31,933
33	Converse	Bexar	Suburban	520	0	0	0	0	10,804	57,160
34	County-Other	Comal	Rural	588	0	0	0	0	0	50,171
35	Niederwald	Hays	Rural	588	0	669	4,571	8,532	15,904	24,465
36	Bexar Met Wd	Bexar	Rural	588	0	0	0	0	0	172,219
37	Kyle	Hays	Suburban	520	0	13,814	49,662	86,993	157,117	230,493
38	Bulverde City	Comal	Suburban	520	0	0	19,554	67,539	135,017	223,786
39	County-Other	Uvalde	Rural	588	0	0	0	19,652	43,068	80,667
40	East Central WSC	Bexar	Rural	588	0	0	0	0	18,972	61,215
41	St. Hedwig	Bexar	Rural	588	0	0	0	0	0	8,219

Table 4C-1-11 Continued

County Number	Water User Group*	County	Area	Cost per Acre-foot	Costs of Water Demand Reduction from Plumbing Fixtures and Clothes Washers Retrofit Conservation					
					2010 (dollars)	2020 (dollars)	2030 (dollars)	2040 (dollars)	2050 (dollars)	2060 (dollars)
42	Aqua WSC	Caldwell	Rural	588	0	0	0	0	3,555	11,247
43	Port Lavaca	Calhoun	Rural	588	0	0	0	0	17,354	52,051
44	Marion	Guadalupe	Rural	588	0	0	0	0	2,046	5,844
45	Waelder	Gonzales	Rural	588	0	0	0	1,972	3,902	6,731
46	County-Other	Medina	Rural	588	0	11,470	24,304	50,613	94,232	143,184
47	Water Ser Inc (APEX)	Bexar	Rural	588	0	0	0	10,531	29,384	61,948
48	Woodcreek	Hays	Rural	588	0	0	1,010	3,463	11,892	21,956
49	Elmendorf	Bexar	Suburban	520	0	0	0	0	1,063	3,094
50	County-Other	La Salle	Rural	588	1,649	2,259	6,511	9,809	17,330	24,945
51	County-Other	Calhoun	Rural	588	0	0	0	0	2,351	6,310
52	Lacoste	Medina	Rural	588	0	0	0	0	2,427	6,580
53	Yorktown	Dewitt	Rural	588	0	928	1,217	1,375	2,956	7,448
54	County-Other	Hays	Rural	588	0	0	7,204	28,662	66,090	108,113
55	Canyon Lake WSC	Comal	Rural	588	0	56,708	149,583	319,201	546,430	772,010
56	Lockhart	Caldwell	Suburban	520	0	0	14,384	53,459	101,274	151,464
57	Oak Hills WSC	Wilson	Rural	588	0	0	0	15,276	44,658	70,015
58	Universal City	Bexar	Suburban	520	0	0	0	0	25,594	51,188
59	Balcones Heights	Bexar	Suburban	520	1,895	2,918	3,799	4,574	10,368	10,890
60	Schertz	Guadalupe	Suburban	520	11,544	45,489	94,418	189,693	320,617	377,183
61	Sunko WSC	Wilson	Rural	588	1,926	3,666	5,667	16,885	26,458	29,998
62	Woodsboro	Refugio	Rural	588	2,973	3,620	4,081	4,511	5,330	5,298
63	Olmos Park	Bexar	Suburban	520	4,844	5,861	6,778	7,531	7,423	7,686
64	Terrell Hills	Bexar	Suburban	520	7,250	9,258	11,080	12,587	12,221	12,683
65	San Antonio	Bexar	Urban	458	2,634,520	3,351,788	4,027,936	3,843,516	3,081,260	3,257,892
66	Yoakum	Dewitt	Rural	588	8,335	9,155	9,774	9,006	5,915	5,809
67	Mountain City	Hays	Rural	588	847	1,773	3,419	4,736	5,981	6,959
68	County Line WSC	Hays	Rural	588	25,017	64,541	103,352	109,374	121,395	138,995
69	County-Other	Zavala	Rural	588	24,681	31,818	41,987	36,737	33,915	35,041
70	Poth	Wilson	Rural	588	11,938	12,821	12,679	10,146	9,026	9,967
71	San Marcos	Hays	Suburban	520	217,098	288,312	370,996	333,400	324,942	368,355
72	Charlotte	Atascosa	Rural	588	11,829	13,277	10,591	6,919	5,738	5,886
73	Encinal	La Salle	Rural	588	5,015	5,122	3,889	2,187	1,765	1,778
74	Luling	Caldwell	Rural	588	41,206	48,088	36,875	22,921	18,588	19,941
75	Natalia	Medina	Rural	588	13,927	16,229	14,956	12,762	11,879	12,721
76	Point Comfort	Calhoun	Rural	588	10,336	14,780	17,540	16,128	10,752	10,752
77	County-Other	Karnes	Rural	588	40,238	52,016	55,861	57,002	59,191	60,179
78	Runge	Karnes	Rural	588	8,972	8,759	6,818	4,502	3,807	3,960
79	Falls City	Karnes	Rural	588	4,450	4,650	3,559	2,717	2,258	2,305
80	Seadrift	Calhoun	Rural	588	11,672	10,571	7,898	5,022	4,049	4,070
81	Goliad	Goliad	Rural	588	17,887	19,634	15,992	10,696	8,987	9,258
82	Victoria	Victoria	Urban	520	454,409	455,284	351,591	229,917	190,618	196,508
83	Yancey WSC	Medina	Rural	588	36,002	40,681	39,284	39,529	38,507	42,025
84	Boerne	Kendall	Rural	588	57,546	72,367	74,068	63,513	72,204	80,704
85	Cuero	Dewitt	Rural	588	58,228	54,401	41,358	27,691	18,184	17,860
86	El Oso WSC	Karnes	Rural	588	24,042	23,836	18,948	15,223	13,285	13,713

Table 4C-1-11 Concluded

County Number	Water User Group*	County	Area	Cost per Acre-foot	Costs of Water Demand Reduction from Plumbing Fixtures and Clothes Washers Retrofit Conservation					
					2010 (dollars)	2020 (dollars)	2030 (dollars)	2040 (dollars)	2050 (dollars)	2060 (dollars)
87	Nixon	Gonzales	Rural	588	20,394	18,366	15,851	10,962	9,231	9,201
88	Refugio	Refugio	Rural	588	25,806	25,904	18,834	14,372	11,945	11,798
89	Springs Hill WSC	Guadalupe	Rural	588	102,348	96,024	88,743	75,493	71,170	80,065
90	County-Other	Caldwell	Rural	588	12,581	11,579	8,425	4,463	2,324	2,110
91	Lytle	Atascosa	Suburban	520	19,859	16,787	12,703	8,184	6,712	6,836
92	Cibolo	Guadalupe	Suburban	520	33,604	40,263	47,856	53,188	64,412	76,500
93	Helotes	Bexar	Suburban	520	59,630	82,562	103,503	110,486	124,505	136,974
94	Jourdanton	Atascosa	Rural	588	35,191	29,962	22,656	17,128	14,340	14,806
95	Castle Hills	Bexar	Suburban	520	31,905	26,981	19,641	12,284	7,376	7,379
96	Devine	Medina	Rural	588	36,887	31,980	20,969	12,288	9,439	9,639
97	Pearsall	Frio	Suburban	520	60,160	52,241	39,883	22,481	18,173	18,271
98	Big Wells	Dimmit	Rural	588	6,570	5,840	4,410	2,766	2,166	2,060
99	Gonzales	Gonzales	Rural	588	68,293	61,112	47,027	36,661	30,887	30,782
100	Hondo	Medina	Rural	588	73,358	67,998	60,664	49,560	44,590	47,544
101	Seguin	Guadalupe	Suburban	520	196,168	187,982	157,017	132,972	124,874	140,018
102	Asherton	Dimmit	Rural	588	11,763	10,117	7,358	4,221	3,096	2,944
103	Floresville	Wilson	Rural	588	80,014	67,584	53,726	42,809	37,943	41,748
104	Woodcreek Utility Inc	Hays	Suburban	520	29,350	40,359	55,135	64,149	80,500	93,360
105	Somerset	Bexar	Suburban	520	14,849	14,230	11,539	10,991	9,984	10,715
106	Kenedy	Karnes	Rural	588	33,057	26,115	19,668	11,914	9,471	9,781
107	Poteet	Atascosa	Rural	588	33,423	27,371	18,621	11,819	9,579	9,669
108	La Vernia	Wilson	Rural	588	11,803	12,425	13,006	12,259	14,491	16,805
109	Pleasanton	Atascosa	Suburban	520	76,258	58,978	44,846	28,987	23,837	24,310
110	New Braunfels	Comal	Suburban	520	382,526	350,568	350,599	366,967	368,329	426,176
111	Stockdale	Wilson	Rural	588	14,320	11,507	9,037	7,136	6,278	6,866
112	China Grove	Bexar	Suburban	520	12,653	10,862	9,908	9,509	8,685	9,360
113	Castroville	Medina	Rural	588	27,423	21,841	16,764	12,883	11,013	11,647
114	Fairoaks Ranch	Bexar	Suburban	520	57,604	54,790	51,692	48,522	45,091	45,461
115	Windcrest	Bexar	Suburban	520	44,935	36,214	27,354	18,369	12,334	12,421
116	Garden Ridge	Comal	Suburban	520	18,022	15,816	13,081	12,972	12,095	13,940
117	Mustang Ridge	Caldwell	Rural	588	4,752	4,422	4,200	4,256	4,100	4,627
118	Sabinal	Uvalde	Rural	588	15,689	12,567	9,437	6,295	4,200	4,202
119	Alamo Heights	Bexar	Suburban	520	67,022	51,508	37,968	23,995	19,410	19,625
120	Dilley	Frio	Rural	588	43,362	40,238	33,717	32,584	30,171	31,033
121	Gonzales County WSC	Caldwell	Rural	588	55,326	45,769	40,441	32,445	27,650	27,650
122	Crystal City	Zavala	Rural	588	74,236	55,881	42,396	26,734	21,582	21,777
123	Carrizo Springs	Dimmit	Rural	588	55,953	46,905	35,435	22,233	17,396	16,543
124	Selma	Bexar	Suburban	520	36,733	36,643	36,025	31,599	27,085	27,085
125	Cotulla	La Salle	Rural	588	37,364	31,936	24,228	15,775	13,144	13,668
126	Uvalde	Uvalde	Rural	588	139,579	111,256	81,872	51,641	31,172	31,315
127	Lackland AFB (CDP)	Bexar	Urban	458	51,160	40,197	29,234	18,271	10,963	10,963
128	Shavano Park	Bexar	Suburban	520	15,779	12,966	8,849	5,635	4,583	4,648
129	Hollywood Park	Bexar	Suburban	520	27,181	20,708	15,564	9,984	8,171	8,334
130	Hill Country Village	Bexar	Suburban	520	8,982	7,185	5,389	3,593	2,395	2,395
	Total				6,054,278	6,859,314	7,546,424	7,444,681	7,694,605	9,976,317

Table 4C.1-12.
Estimated Costs for Projected Municipal Water Conservation from Lawn Irrigation
South Central Texas Water Planning Region

County Number	Water User Group*	County	Area	Cost per Acre-foot	Costs of Water Demand Reduction from Lawn Irrigation Conservation					
					2010 (dollars)	2020 (dollars)	2030 (dollars)	2040 (dollars)	2050 (dollars)	2060 (dollars)
1	Calhoun County WS	Calhoun	Rural	400	0	0	0	0	0	0
2	County-Other	Wilson	Rural	400	0	0	0	0	0	0
3	Green Valley SUD	Guadalupe	Rural	400	0	0	0	0	0	0
4	Polonia WSC	Caldwell	Rural	400	0	0	0	0	0	0
5	County-Other	Victoria	Rural	400	0	0	0	0	0	0
6	Benton City WSC	Atascosa	Rural	400	0	0	0	0	0	0
7	County-Other	Dimmit	Rural	400	0	0	0	0	0	0
8	County-Other	Goliad	Rural	400	0	0	0	0	0	0
9	Creedmoor-Maha WSC	Caldwell	Rural	400	0	0	0	0	0	0
10	Goforth WSC	Hays	Rural	400	0	0	0	0	0	0
11	Crystal Clear WSC	Guadalupe	Rural	400	0	0	0	0	0	0
12	Martindale	Caldwell	Rural	400	0	0	0	0	0	0
13	Plum Creek Water Co.	Hays	Rural	400	0	0	0	0	0	0
14	County-Other	Refugio	Rural	400	0	0	0	0	0	0
15	McCoy WSC	Atascosa	Rural	400	0	0	0	0	0	0
16	Atascosa Rural WSC	Bexar	Rural	400	0	0	0	0	0	0
17	County-Other	Atascosa	Rural	400	0	0	0	0	0	0
18	County-Other	Kendall	Rural	400	0	0	0	0	0	0
19	Wimberley WSC	Hays	Rural	400	0	0	0	0	0	0
20	Kirby	Bexar	Rural	400	0	0	0	0	0	0
21	County-Other	Dewitt	Rural	400	0	0	0	0	0	0
22	County-Other	Frio	Rural	400	0	0	0	0	0	0
23	Karnes City	Karnes	Rural	400	0	0	0	0	0	0
24	Leon Valley	Bexar	Suburban	400	0	0	0	0	0	0
25	Maxwell WSC	Caldwell	Rural	400	0	0	0	0	0	0
26	Live Oak	Bexar	Suburban	400	0	0	0	0	0	0
27	Ss WSC	Wilson	Rural	400	0	0	0	0	0	0
28	County-Other	Gonzales	Rural	400	0	0	0	0	0	0
29	County-Other	Guadalupe	Rural	400	0	0	0	0	0	0
30	Santa Clara	Guadalupe	Rural	400	0	0	0	0	0	0
31	County-Other	Bexar	Rural	400	0	0	0	0	0	0
32	East Medina SUD	Medina	Rural	400	0	0	0	0	0	0
33	Converse	Bexar	Suburban	400	0	0	0	0	0	0
34	County-Other	Comal	Rural	400	0	0	0	0	0	0
35	Niederwald	Hays	Rural	400	0	0	0	0	0	0
36	Bexar Met Wd	Bexar	Rural	400	0	0	0	0	0	0
37	Kyle	Hays	Suburban	400	0	0	0	0	0	0
38	Bulverde City	Comal	Suburban	400	0	0	0	0	0	0
39	County-Other	Uvalde	Rural	400	0	0	0	0	0	0
40	East Central WSC	Bexar	Rural	400	0	0	0	0	0	0
41	St. Hedwig	Bexar	Rural	400	0	0	0	0	0	0

Table 4C-1-12 Continued

County Number	Water User Group*	County	Area	Cost per Acre-foot	Costs of Water Demand Reduction from Lawn Irrigation Conservation					
					2010 (dollars)	2020 (dollars)	2030 (dollars)	2040 (dollars)	2050 (dollars)	2060 (dollars)
42	Aqua WSC	Caldwell	Rural	400	0	0	0	0	0	0
43	Port Lavaca	Calhoun	Rural	400	0	0	0	0	0	0
44	Marion	Guadalupe	Rural	400	0	0	0	0	0	0
45	Waelder	Gonzales	Rural	400	0	0	0	0	0	0
46	County-Other	Medina	Rural	400	0	0	0	0	0	0
47	Water Ser Inc (APEX)	Bexar	Rural	400	0	0	0	0	0	0
48	Woodcreek	Hays	Rural	400	0	0	0	0	0	0
49	Elmendorf	Bexar	Suburban	400	0	0	0	0	0	0
50	County-Other	La Salle	Rural	400	0	0	0	0	0	0
51	County-Other	Calhoun	Rural	400	0	0	0	0	0	0
52	Lacoste	Medina	Rural	400	0	0	0	0	0	0
53	Yorktown	Dewitt	Rural	400	0	0	0	0	0	0
54	County-Other	Hays	Rural	400	0	0	0	0	0	0
55	Canyon Lake WSC	Comal	Rural	400	0	0	0	0	0	40,398
56	Lockhart	Caldwell	Suburban	400	0	0	0	0	0	16,644
57	Oak Hills WSC	Wilson	Rural	400	0	0	0	0	0	6,804
58	Universal City	Bexar	Suburban	400	0	0	0	0	0	19,688
59	Balcones Heights	Bexar	Suburban	400	0	0	0	0	0	6,283
60	Schertz	Guadalupe	Suburban	400	0	0	0	0	30,829	145,070
61	Sunko WSC	Wilson	Rural	400	0	0	0	0	3,600	16,325
62	Woodsboro	Refugio	Rural	400	0	0	0	0	1,813	4,505
63	Olmos Park	Bexar	Suburban	400	0	0	0	0	2,855	7,391
64	Terrell Hills	Bexar	Suburban	400	0	0	0	0	6,267	16,260
65	San Antonio	Bexar	Urban	400	0	0	0	839,196	3,588,075	6,639,081
66	Yoakum	Dewitt	Rural	400	0	0	0	1,021	4,024	6,916
67	Mountain City	Hays	Rural	400	0	0	0	716	2,260	4,208
68	County Line WSC	Hays	Rural	400	0	0	0	16,534	55,055	94,554
69	County-Other	Zavala	Rural	400	0	0	0	10,710	23,071	35,756
70	Poth	Wilson	Rural	400	0	0	1,232	4,141	12,280	18,645
71	San Marcos	Hays	Suburban	400	0	0	40,769	256,461	499,910	779,212
72	Charlotte	Atascosa	Rural	400	0	0	2,702	5,648	9,759	13,012
73	Encinal	La Salle	Rural	400	0	290	1,470	2,380	3,302	4,234
74	Luling	Caldwell	Rural	400	0	3,271	17,918	31,185	46,364	63,305
75	Natalia	Medina	Rural	400	0	1,203	5,178	9,771	14,944	20,527
76	Point Comfort	Calhoun	Rural	400	0	3,631	10,257	20,215	26,134	31,907
77	County-Other	Karnes	Rural	400	0	12,939	24,928	38,299	50,648	62,281
78	Runge	Karnes	Rural	400	0	2,773	4,944	7,259	9,773	12,294
79	Falls City	Karnes	Rural	400	0	1,868	3,224	4,676	6,104	7,474
80	Seadrift	Calhoun	Rural	400	0	4,376	6,793	9,189	11,501	13,756
81	Goliad	Goliad	Rural	400	0	10,047	15,915	21,899	27,983	33,837
82	Victoria	Victoria	Urban	400	0	288,613	422,572	560,618	700,746	842,801
83	Yancey WSC	Medina	Rural	400	0	26,794	41,851	58,670	77,579	97,718
84	Boerne	Kendall	Rural	400	0	62,597	107,206	157,775	211,600	271,650
85	Cuero	Dewitt	Rural	400	0	35,293	46,559	57,323	66,612	75,145
86	El Oso WSC	Karnes	Rural	400	0	16,870	23,997	31,513	38,933	46,158

Table 4C-1-12 Concluded

County Number	Water User Group*	County	Area	Cost per Acre-foot	Costs of Water Demand Reduction from Lawn Irrigation Conservation					
					2010 (dollars)	2020 (dollars)	2030 (dollars)	2040 (dollars)	2050 (dollars)	2060 (dollars)
87	Nixon	Gonzales	Rural	400	0	12,998	17,844	22,694	27,052	30,972
88	Refugio	Refugio	Rural	400	0	20,167	27,260	35,701	43,758	49,639
89	Springs Hill WSC	Guadalupe	Rural	400	0	87,009	130,519	176,966	232,113	296,138
90	County-Other	Caldwell	Rural	400	0	7,090	8,644	9,318	9,794	10,050
91	Lytle	Atascosa	Suburban	400	0	16,064	23,087	28,065	33,041	37,887
92	Cibolo	Guadalupe	Suburban	400	0	39,555	75,506	108,694	149,879	199,146
93	Helotes	Bexar	Suburban	400	0	74,350	136,087	184,735	237,036	291,739
94	Jourdanton	Atascosa	Rural	400	0	29,005	46,935	57,607	68,383	78,759
95	Castle Hills	Bexar	Suburban	400	0	27,193	41,782	48,253	54,574	60,734
96	Devine	Medina	Rural	400	0	28,864	46,728	55,053	63,511	71,950
97	Pearsall	Frio	Suburban	400	0	48,874	78,168	91,113	103,703	115,668
98	Big Wells	Dimmit	Rural	400	0	5,336	8,903	10,221	11,230	11,822
99	Gonzales	Gonzales	Rural	400	0	56,535	98,167	116,265	131,571	144,756
100	Hondo	Medina	Rural	400	0	69,196	126,633	157,172	189,943	223,584
101	Seguin	Guadalupe	Suburban	400	0	196,642	370,626	476,842	601,489	744,563
102	Asherton	Dimmit	Rural	400	0	10,420	18,134	20,662	22,557	23,625
103	Floresville	Wilson	Rural	400	0	70,448	136,634	172,405	212,612	257,106
104	Woodcreek Util Inc	Hays	Suburban	400	0	39,642	92,488	132,789	185,478	236,419
105	Somerset	Bexar	Suburban	400	0	17,171	35,241	44,013	53,128	62,414
106	Kenedy	Karnes	Rural	400	883	30,781	62,117	78,245	90,227	100,529
107	Poteet	Atascosa	Rural	400	1,268	27,731	52,695	66,079	72,499	78,644
108	La Vernia	Wilson	Rural	400	535	13,873	32,970	49,941	63,838	79,471
109	Pleasanton	Atascosa	Suburban	400	3,646	74,463	144,625	186,934	207,803	227,490
110	New Braunfels	Comal	Suburban	400	31,654	516,333	1,183,308	1,890,792	2,376,503	2,932,988
111	Stockdale	Wilson	Rural	400	1,114	15,130	31,054	46,331	54,626	63,659
112	China Grove	Bexar	Suburban	400	1,271	18,114	38,784	59,189	69,473	79,719
113	Castroville	Medina	Rural	400	2,517	29,530	58,881	88,014	100,515	112,986
114	Fairoaks Ranch	Bexar	Suburban	400	5,495	56,357	103,392	146,561	157,545	168,672
115	Windcrest	Bexar	Suburban	400	5,233	47,829	86,934	122,879	135,253	144,287
116	Garden Ridge	Comal	Suburban	400	2,932	29,083	64,542	107,432	142,396	173,252
117	Mustang Ridge	Caldwell	Rural	400	803	7,495	16,240	26,776	36,504	43,351
118	Sabinal	Uvalde	Rural	400	2,977	17,273	30,237	41,968	52,593	55,295
119	Alamo Heights	Bexar	Suburban	400	18,322	95,202	166,158	231,722	292,569	330,776
120	Dilley	Frio	Rural	400	12,175	64,028	121,963	182,180	240,236	287,692
121	Gonzales County WSC	Caldwell	Rural	400	19,472	93,633	174,415	255,260	324,570	382,022
122	Crystal City	Zavala	Rural	400	26,317	107,703	188,476	259,624	325,383	386,170
123	Carrizo Springs	Dimmit	Rural	400	22,552	93,042	161,454	220,912	268,111	299,712
124	Selma	Bexar	Suburban	400	25,719	109,403	218,967	296,133	365,434	428,108
125	Cotulla	La Salle	Rural	400	21,830	77,376	131,303	184,450	237,011	288,689
126	Uvalde	Uvalde	Rural	400	113,327	330,944	532,509	717,798	886,275	1,039,433
127	Lackland AFB (CDP)	Bexar	Urban	400	62,483	170,946	269,037	357,750	437,980	510,538
128	Shavano Park	Bexar	Suburban	400	17,003	46,789	75,048	101,490	126,169	149,063
129	Hollywood Park	Bexar	Suburban	400	63,809	149,817	232,887	311,482	385,702	455,242
130	Hill Country Village	Bexar	Suburban	400	23,904	53,020	79,352	103,167	124,704	144,182
	Total				487,240	3,603,020	6,554,251	10,226,875	15,536,793	21,362,786

Table 4C.1-13.
Estimated Costs for Projected Municipal Water Conservation from Additional Plumbing Fixtures and Clothes Washers Retrofit and Lawn Irrigation South Central Texas Water Planning Region

County Number	Water User Group*	County	Area	Costs of Water Demand Reduction from Plumbing Fixtures and Clothes Washers Retrofit plus Lawn Irrigation Conservation					
				2010 (dollars)	2020 (dollars)	2030 (dollars)	2040 (dollars)	2050 (dollars)	2060 (dollars)
1	Calhoun County WS	Calhoun	Rural	0	0	0	0	0	0
2	County-Other	Wilson	Rural	0	0	0	8,050	34,243	68,476
3	Green Valley SUD	Guadalupe	Rural	0	0	0	0	0	11,992
4	Polonia WSC	Caldwell	Rural	0	0	0	0	0	0
5	County-Other	Victoria	Rural	0	0	0	0	0	18,878
6	Benton City WSC	Atascosa	Rural	0	0	0	13,964	49,748	89,732
7	County-Other	Dimmit	Rural	0	0	0	0	0	0
8	County-Other	Goliad	Rural	0	0	0	0	0	9,670
9	Creedmoor-Maha WSC	Caldwell	Rural	0	0	0	0	0	6,644
10	Goforth WSC	Hays	Rural	0	0	0	0	13,133	65,352
11	Crystal Clear WSC	Guadalupe	Rural	0	0	0	0	24,036	108,003
12	Martindale	Caldwell	Rural	0	0	0	0	0	0
13	Plum Creek Water Co.	Hays	Rural	0	0	0	0	7,201	31,722
14	County-Other	Refugio	Rural	0	0	0	0	0	0
15	McCoy WSC	Atascosa	Rural	0	0	0	7,775	39,895	75,669
16	Atascosa Rural WSC	Bexar	Rural	0	0	0	0	0	13,044
17	County-Other	Atascosa	Rural	6,532	9,779	6,515	810	0	0
18	County-Other	Kendall	Rural	0	0	0	0	43,086	155,415
19	Wimberley WSC	Hays	Rural	0	0	0	0	11,207	40,963
20	Kirby	Bexar	Rural	0	0	0	0	0	0
21	County-Other	Dewitt	Rural	0	0	0	0	0	3,789
22	County-Other	Frio	Rural	0	0	0	0	0	10,572
23	Karnes City	Karnes	Rural	0	0	0	0	0	6,532
24	Leon Valley	Bexar	Suburban	0	0	0	0	0	6,079
25	Maxwell WSC	Caldwell	Rural	0	0	0	0	6,567	32,475
26	Live Oak	Bexar	Suburban	0	0	0	0	0	0
27	Ss WSC	Wilson	Rural	0	0	0	0	49,321	129,665
28	County-Other	Gonzales	Rural	3,659	4,216	2,986	0	0	1,831
29	County-Other	Guadalupe	Rural	1,107	0	0	0	0	124
30	Santa Clara	Guadalupe	Rural	0	0	6,015	13,335	27,662	46,643
31	County-Other	Bexar	Rural	28,834	56,217	82,441	112,410	182,263	297,122
32	East Medina SUD	Medina	Rural	0	0	0	0	11,266	31,933
33	Converse	Bexar	Suburban	0	0	0	0	10,804	57,160
34	County-Other	Comal	Rural	0	0	0	0	0	50,171
35	Niederwald	Hays	Rural	0	669	4,571	8,532	15,904	24,465
36	Bexar Met Wd	Bexar	Rural	0	0	0	0	0	172,219
37	Kyle	Hays	Suburban	0	13,814	49,662	86,993	157,117	230,493
38	Bulverde City	Comal	Suburban	0	0	19,554	67,539	135,017	223,786
39	County-Other	Uvalde	Rural	0	0	0	19,652	43,068	80,667
40	East Central WSC	Bexar	Rural	0	0	0	0	18,972	61,215
41	St. Hedwig	Bexar	Rural	0	0	0	0	0	8,219

Table 4C-1-13 Continued

County Number	Water User Group*	County	Area	Costs of Water Demand Reduction from Plumbing Fixtures and Clothes Washers Retrofit plus Lawn Irrigation Conservation					
				2010 (dollars)	2020 (dollars)	2030 (dollars)	2040 (dollars)	2050 (dollars)	2060 (dollars)
42	Aqua WSC	Caldwell	Rural	0	0	0	0	3,555	11,247
43	Port Lavaca	Calhoun	Rural	0	0	0	0	17,354	52,051
44	Marion	Guadalupe	Rural	0	0	0	0	2,046	5,844
45	Waelder	Gonzales	Rural	0	0	0	1,972	3,902	6,731
46	County-Other	Medina	Rural	0	11,470	24,304	50,613	94,232	143,184
47	Water Ser Inc (APEX)	Bexar	Rural	0	0	0	10,531	29,384	61,948
48	Woodcreek	Hays	Rural	0	0	1,010	3,463	11,892	21,956
49	Elmendorf	Bexar	Suburban	0	0	0	0	1,063	3,094
50	County-Other	La Salle	Rural	1,649	2,259	6,511	9,809	17,330	24,945
51	County-Other	Calhoun	Rural	0	0	0	0	2,351	6,310
52	Lacoste	Medina	Rural	0	0	0	0	2,427	6,580
53	Yorktown	Dewitt	Rural	0	928	1,217	1,375	2,956	7,448
54	County-Other	Hays	Rural	0	0	7,204	28,662	66,090	108,113
55	Canyon Lake WSC	Comal	Rural	0	56,708	149,583	319,201	546,430	812,408
56	Lockhart	Caldwell	Suburban	0	0	14,384	53,459	101,274	168,109
57	Oak Hills WSC	Wilson	Rural	0	0	0	15,276	44,658	76,819
58	Universal City	Bexar	Suburban	0	0	0	0	25,594	70,876
59	Balcones Heights	Bexar	Suburban	1,895	2,918	3,799	4,574	10,368	17,173
60	Schertz	Guadalupe	Suburban	11,544	45,489	94,418	189,693	351,446	522,253
61	Sunko WSC	Wilson	Rural	1,926	3,666	5,667	16,885	30,057	46,323
62	Woodsboro	Refugio	Rural	2,973	3,620	4,081	4,511	7,143	9,803
63	Olmos Park	Bexar	Suburban	4,844	5,861	6,778	7,531	10,278	15,077
64	Terrell Hills	Bexar	Suburban	7,250	9,258	11,080	12,587	18,489	28,943
65	San Antonio	Bexar	Urban	2,634,520	3,351,788	4,027,936	4,682,712	6,669,335	9,896,973
66	Yoakum	Dewitt	Rural	8,335	9,155	9,774	10,027	9,938	12,725
67	Mountain City	Hays	Rural	847	1,773	3,419	5,452	8,242	11,167
68	County Line WSC	Hays	Rural	25,017	64,541	103,352	125,908	176,450	233,550
69	County-Other	Zavala	Rural	24,681	31,818	41,987	47,447	56,986	70,798
70	Poth	Wilson	Rural	11,938	12,821	13,911	14,288	21,306	28,612
71	San Marcos	Hays	Suburban	217,098	288,312	411,764	589,861	824,852	1,147,567
72	Charlotte	Atascosa	Rural	11,829	13,277	13,293	12,567	15,497	18,898
73	Encinal	La Salle	Rural	5,015	5,412	5,358	4,567	5,067	6,012
74	Luling	Caldwell	Rural	41,206	51,359	54,793	54,106	64,951	83,246
75	Natalia	Medina	Rural	13,927	17,432	20,134	22,533	26,823	33,248
76	Point Comfort	Calhoun	Rural	10,336	18,411	27,797	36,343	36,886	42,658
77	County-Other	Karnes	Rural	40,238	64,955	80,789	95,300	109,839	122,460
78	Runge	Karnes	Rural	8,972	11,532	11,763	11,761	13,580	16,254
79	Falls City	Karnes	Rural	4,450	6,518	6,783	7,393	8,362	9,779
80	Seadrift	Calhoun	Rural	11,672	14,947	14,691	14,211	15,550	17,827
81	Goliad	Goliad	Rural	17,887	29,681	31,907	32,596	36,970	43,095
82	Victoria	Victoria	Urban	454,409	743,898	774,163	790,535	891,364	1,039,310
83	Yancey WSC	Medina	Rural	36,002	67,475	81,135	98,199	116,086	139,743
84	Boerne	Kendall	Rural	57,546	134,963	181,274	221,288	283,804	352,354
85	Cuero	Dewitt	Rural	58,228	89,694	87,918	85,014	84,796	93,005
86	El Oso WSC	Karnes	Rural	24,042	40,706	42,945	46,735	52,217	59,871

Table 4C-1-13 Concluded

County Number	Water User Group*	County	Area	Costs of Water Demand Reduction from Plumbing Fixtures and Clothes Washers Retrofit plus Lawn Irrigation Conservation					
				2010 (dollars)	2020 (dollars)	2030 (dollars)	2040 (dollars)	2050 (dollars)	2060 (dollars)
87	Nixon	Gonzales	Rural	20,394	31,365	33,695	33,656	36,283	40,173
88	Refugio	Refugio	Rural	25,806	46,071	46,094	50,073	55,703	61,436
89	Springs Hill WSC	Guadalupe	Rural	102,348	183,033	219,262	252,458	303,283	376,203
90	County-Other	Caldwell	Rural	12,581	18,669	17,070	13,780	12,118	12,160
91	Lytle	Atascosa	Suburban	19,859	32,851	35,789	36,249	39,754	44,723
92	Cibolo	Guadalupe	Suburban	33,604	79,818	123,362	161,882	214,291	275,647
93	Helotes	Bexar	Suburban	59,630	156,913	239,591	295,221	361,541	428,713
94	Jourdanton	Atascosa	Rural	35,191	58,966	69,591	74,735	82,723	93,565
95	Castle Hills	Bexar	Suburban	31,905	54,174	61,423	60,537	61,950	68,114
96	Devine	Medina	Rural	36,887	60,844	67,697	67,340	72,950	81,588
97	Pearsall	Frio	Suburban	60,160	101,115	118,051	113,594	121,876	133,939
98	Big Wells	Dimmit	Rural	6,570	11,176	13,313	12,987	13,395	13,883
99	Gonzales	Gonzales	Rural	68,293	117,647	145,194	152,927	162,458	175,538
100	Hondo	Medina	Rural	73,358	137,194	187,297	206,732	234,533	271,129
101	Seguin	Guadalupe	Suburban	196,168	384,624	527,643	609,814	726,363	884,582
102	Asherton	Dimmit	Rural	11,763	20,537	25,492	24,883	25,654	26,569
103	Floresville	Wilson	Rural	80,014	138,031	190,360	215,214	250,555	298,854
104	Woodcreek Util Inc	Hays	Suburban	29,350	80,000	147,623	196,938	265,978	329,778
105	Somerset	Bexar	Suburban	14,849	31,401	46,780	55,004	63,112	73,129
106	Kenedy	Karnes	Rural	33,941	56,896	81,786	90,158	99,698	110,310
107	Poteet	Atascosa	Rural	34,691	55,102	71,316	77,899	82,078	88,313
108	La Vernia	Wilson	Rural	12,338	26,299	45,976	62,200	78,329	96,276
109	Pleasanton	Atascosa	Suburban	79,904	133,442	189,471	215,921	231,640	251,800
110	New Braunfels	Comal	Suburban	414,181	866,901	1,533,907	2,257,759	2,744,832	3,359,164
111	Stockdale	Wilson	Rural	15,435	26,636	40,091	53,468	60,904	70,524
112	China Grove	Bexar	Suburban	13,924	28,976	48,692	68,699	78,158	89,080
113	Castroville	Medina	Rural	29,940	51,371	75,645	100,897	111,528	124,634
114	Fairoaks Ranch	Bexar	Suburban	63,099	111,147	155,084	195,084	202,635	214,133
115	Windcrest	Bexar	Suburban	50,168	84,043	114,288	141,248	147,588	156,708
116	Garden Ridge	Comal	Suburban	20,953	44,899	77,624	120,404	154,491	187,192
117	Mustang Ridge	Caldwell	Rural	5,555	11,918	20,440	31,032	40,604	47,978
118	Sabinal	Uvalde	Rural	18,665	29,840	39,674	48,263	56,792	59,497
119	Alamo Heights	Bexar	Suburban	85,345	146,709	204,126	255,717	311,979	350,401
120	Dilley	Frio	Rural	55,537	104,266	155,680	214,764	270,407	318,725
121	Gonzales County WSC	Caldwell	Rural	74,798	139,402	214,856	287,705	352,220	409,672
122	Crystal City	Zavala	Rural	100,553	163,584	230,872	286,358	346,965	407,948
123	Carrizo Springs	Dimmit	Rural	78,506	139,947	196,889	243,145	285,507	316,254
124	Selma	Bexar	Suburban	62,452	146,047	254,992	327,732	392,519	455,193
125	Cotulla	La Salle	Rural	59,194	109,313	155,531	200,225	250,155	302,357
126	Uvalde	Uvalde	Rural	252,905	442,200	614,381	769,439	917,448	1,070,747
127	Lackland AFB (CDP)	Bexar	Urban	113,643	211,143	298,272	376,021	448,943	521,501
128	Shavano Park	Bexar	Suburban	32,782	59,754	83,897	107,125	130,752	153,711
129	Hollywood Park	Bexar	Suburban	90,990	170,525	248,451	321,466	393,873	463,576
130	Hill Country Village	Bexar	Suburban	32,886	60,205	84,741	106,759	127,099	146,577
	Total			6,541,518	10,462,334	14,100,675	17,671,556	23,231,398	31,339,103

described at the beginning of this analysis, in 2010 is $6,541,518 ($494/acft/yr), increasing to $14,100,675 ($446/acft/yr) in 2030, and to $31,339,103 in 2060 ($432/acft/yr) (Table 4C.1-13). As the quantity of water conservation (demand reduction) increases, the unit cost decreases from $494 per acre-foot in 2010, to $446 per acre-foot in 2030, and to $432 per acre-foot in 2060.

4C.1.2 Irrigation Water Conservation (L-10 Irr.)

Irrigation water use is the use of freshwater that is pumped from aquifers and/or diverted from streams and reservoirs of the planning area and applied directly to grow crops, orchards, and hay and pasture in the study area. In the case of groundwater in Region L, irrigation wells are usually located within the fields to be irrigated, such that the irrigation water is taken directly from the wells and applied to the land by: (1) flowing or flooding water down the furrows; and (2) with the use of sprinklers. In the case of surface water from planning area streams and reservoirs, water is diverted from the source and conveyed by canals and pipelines to the fields where it is then applied by: (1) flowing or flooding water down the furrows; and (2) with the use of sprinklers. In both the use of groundwater and surface water, the conservation objective is to reduce the quantity of water that is lost to deep percolation and evaporation between the originating points (wells in the case of groundwater, and stream diversion points in the case of surface water), and the irrigated crops in the fields. Thus, the focus is upon investments in irrigation application equipment, instruments, and conveyance facility improvements (canal lining and pipelines) to reduce seepage losses, deep percolation, and evaporation of water between the originating points of the water and the destination locations within the irrigated fields, and management of the irrigation processes to improve efficiencies of irrigation water use and reduce the quantities of water needed to accomplish irrigation.

The Water Conservation Implementation Task Force list of Best Management Practices (BMPs) for irrigation is as follows:[7]

1. Irrigation Scheduling;
2. Volumetric Measurement of Irrigation Water Use;
3. Crop Residue Management and Conservation Tillage;
4. On-farm Irrigation audit;
5. Furrow Dikes;
6. Land Leveling;
7. Contour Farming;

[7] Water Conservation Implementation Task Force, Report to the 79th Legislature, Texas Water Development Board, Special Report, Austin, Texas, November 2004.

8. Conservation of Supplemental Irrigated Farmland to Dry-Land Farmland;
9. Brush Control/Management;
10. Lining of On-Farm Irrigation ditches;
11. Replacement of On-/farm Irrigation Ditches with Pipelines;
12. Low Pressure Center Pivot Sprinkler Irrigation Systems;
13. Drip/Micro-Irrigation System;
14. Gated and Flexible Pipe for Field Water Distribution Systems;
15. Surge Flow Irrigation for Field Water Distribution Systems;
16. Linear Move Sprinkler Irrigation Systems;
17. Lining of District Irrigation Canals;
18. Replacement of District Irrigation canals and Lateral canals with Pipelines;
19. Tailwater Recovery and Use System; and
20. Nursery Production Systems.

Principal methods of irrigation water conservation on irrigation farms of Region L are: (1) low-pressure sprinklers (LESA); (2) low-energy precision application systems (LEPA); and (3) irrigation scheduling. In comparison to the irrigation method (furrow or flood irrigation) of releasing the water into the furrows at the ends of the rows and allowing it to flow across the fields until each furrow has been saturated throughout its entire length, the use of LESA, LEPA, and irrigation scheduling all improve application efficiency within the irrigated fields and thereby reduce the total quantity of water needed to produce an irrigated crop. The major irrigation water conservation techniques applicable in the South Central Texas Water Planning Region are described briefly below.

Low-pressure sprinklers spray water into the atmosphere above the crops as the sprinkler systems are moved across the fields. LEPA systems involve a sprinkler system that has been modified to discharge water directly into furrows at low pressure, thus reducing evaporation losses. When used in conjunction with furrow dikes, which hold both precipitation and sprinkler applied water behind small mounds of earth within the furrows, LEPA systems can accomplish the irrigation objective with less water than is required for the furrow irrigation and pressurized sprinkler methods. (Note: Furrow dikes are constructed by towing the furrow-diking implement behind planters or cultivators when these operations are performed. The furrow dikes hold water in place within the furrows, allowing it to infiltrate the soil profile as opposed to allowing the water to flow down the furrows and exit the fields. Furrow dikes have been demonstrated to be useful management tools on both irrigated and non-irrigated cropland.)

Low-pressure sprinklers (LESA) and surge valves improve irrigation application efficiency in comparison to furrow irrigation by reducing water requirements per acre in the

10 to 15 percent range, while LEPA combined with furrow diking can reduce water requirements per acre by 30 to 40 percent. In the Edwards Aquifer area of the Region (Bexar, Medina, and Uvalde Counties), conversion from furrow irrigation to LEPA systems with furrow diking would save about 0.8 acft/acre converted.[8] In the major irrigation counties of the Carrizo Aquifer area of the Region (Atascosa, Frio, and Zavala), the water savings through use of LEPA/Furrow Dike systems is estimated at 0.25 to 0.30 acft/acre. Use of LEPA and furrow dikes allows irrigation farmers to produce equivalent yields per acre at lower energy and labor costs of irrigation. It has been demonstrated that LEPA systems improve production and profitability of irrigation farming. The barriers to installation are high capital costs, with no assurance (at the present time) that the water saved in the Carrizo Aquifer from the investment would be available to the irrigation farmer who incurred the costs. However, under the Edwards Aquifer Authority's regulatory powers, the water conservation investor could be assured ownership of the conservation savings.

The TWDB irrigation water demand projections for the South Central Texas Region show significant decreases in irrigation usage in the future. For example, the TWDB estimates of irrigation water use in the 21 counties of the South Central Texas Region was 669,440 acft/yr in 1990 and are 383,332 acft/yr in 2000 (Table 4C.1-8), with projections to 2030 of 344,777 acft/yr and to 2060 of 301,679 acft/yr (Section 2.0, Table 2-8). For the South Central Texas Region, irrigation water use declined between 1990 and 2000 by 286,108 acft/yr, with the projections showing further reductions between 2000 and 2030 of 38,555 acft/yr and between 2030 and 2060 of an additional 43,098 acft/yr (Section 2.0, Table 2-8).

Calculated irrigation water use rates for the Edwards Aquifer area counties showed a 46 percent decline from 2.39 acre-feet per acre in 1990 to 1.28 acre-feet per acre in 2000 (Table 4C.1-14). Water use rates for the Carrizo Aquifer area counties showed a 7.3 percent decline from 1.5 acre-feet per acre in 1990 to 1.39 acre-feet per acre in 2000 (Table 4C.1-14), Gulf Coast Aquifer area counties irrigation use rates declined 12.6 percent from 1.98 acre-feet per acre to 1.73 acre-feet per acre, Calhoun County, which uses surface water, showed a 24 percent decline from 5.71 acre-feet per acre in 1990 to 4.33 acre-feet per acre in 2000. Finally, Hill Country counties showed a 26 percent decline from 1.95 acre-feet per acre in 1990 to 1.00 acre-feet per

[8] Pena, Jose G., and Robert Jenson, "Irrigation Water Use Conservation Potential and the Economic Implications of Adopting More Efficient Irrigation Technology, the Case in Uvalde County," Water for South Texas, Texas Agricultural Experiment Station, Texas A & M University, College Station, Texas, CPR - 5043-5046, October 1992.

acre in 2000 (Table 4C.1-14). Overall, the South Central Texas Water Planning Region average irrigation use rate per acre declined 29 percent from 1.95 acre-feet per acre in 1990 to 1.38 acre-feet per acre in 2000 (Table 4C.1-14).

Table 4C.1-14.
Irrigated Acreages, Irrigation Water Use, and Irrigation Application Rates
South Central Texas Water Planning Region – 1990 and 2000

County	1990			2000		
	Acres Irrigated	Irrigation Water Use (acft)	Irrigation Use Rate (acft/acre)	Acres Irrigated	Irrigation Water Use (acft)	Irrigation Use Rate (acft/acre)
Edward Aquifer Area Counties						
Bexar	18,420	36,051	1.96	7,885	15,865	2.01
Medina	55,600	149,412	2.69	44,755	56,422	1.26
Uvalde	66,020	140,669	2.13	48,940	58,061	1.19
Subtotal	140,040	326,132	2.33	101,580	130,348	1.28
Carrizo Aquifer Area Counties						
Atascosa	43,050	47,208	1.10	35,796	35,053	0.98
Caldwell	1,335	1,375	1.03	1,593	989	0.62
Dimmit	7,525	10,425	1.39	5,262	6,750	1.28
Frio	61,300	83,233	1.36	69,845	117,098	1.68
Gonzales	3,350	3,540	1.06	3,039	2,438	0.80
Guadalupe	2,780	2,646	0.95	665	875	1.32
La Salle	8,150	7,292	0.89	3,584	4,003	1.12
Wilson	12,820	13,697	1.07	14,122	20,883	1.48
Zavala	47,000	107,459	2.29	34,309	46,275	1.35
Subtotal	187,310	276,875	1.48	168,215	234,364	1.39
Gulf Coast Aquifer Area Counties						
DeWitt	620	285	0.46	467	102	0.22
Goliad	970	685	0.71	386	359	0.93
Karnes	1,915	2,034	1.06	1,350	1,916	1.42
Refugio	0	0	0.00	1,130	850	0.75
Victoria	4,920	13,699	2.78	2,411	6,708	2.78
Subtotal	8,425	16,703	1.98	5,744	9,935	1.73
Gulf Coast Surface Water Counties						
Calhoun	6,200	16,533	2.67	1,864	8,077	4.33
Subtotal	6,200	16,533	2.67	1,864	8,077	4.33
Hill Country Area Counties						
Comal	375	479	1.28	121	50	0.41
Hays (part)	274	298	1.09	176	162	0.92
Kendall	205	380	1.85	312	396	1.27
Subtotal	854	1,157	1.35	609	608	1.00
Region L Totals	**342,829**	**637,400**	**1.86**	**278,013**	**383,332**	**1.38**
* Texas Water Development Board.						

Given that the technological limits of irrigation conservation potential were in the range of 20 to 40 percent of the level of use in the 1990s, and that much of this potential appears to have been reached by year 2000 (Table 4C.1-14), the irrigation water conservation water management strategy appears to be quite limited insofar as utility for meeting projected irrigation needs (shortages). However, the irrigation water conservation water management strategy will be developed for Atascosa, Bexar, Kendall, Medina, and Zavala Counties, since these are the counties for which there are projected irrigation water needs (shortages) (Table 4C.1-15).

Table 4C.1-15.
Projected Irrigation Water Needs (Shortages)
South Central Texas Water Planning Region

County	2010 (acft)	2020 (acft)	2030 (acft)	2040 (acft)	2050 (acft)	2060 (acft)
Atascosa	1,961	1,022	111	0	0	0
Bexar	184	150	529	489	452	417
Kendall	148	145	141	138	143	140
Medina	4,651	2,887	1,200	0	0	0
Zavala	48,165	45,344	42,621	40,005	37,492	34,078
Total	55,109	49,548	44,602	40,632	38,087	35,635

The estimates of quantities and costs of the water conservation water management strategy for irrigation in Atascosa, Bexar, Kendall, Medina, and Zavala Counties are based upon the assumption that the irrigation water conservation method having the most potential is the LEPA System in conjunction with furrow dikes, and that the following conditions and assumptions apply:

- Conservation result is 20 percent of irrigation rate;
- Irrigation rate from which to estimate water savings from conservation is that calculated for year 2000, and is shown for each county in Table 4C.1-14; and
- Cost to install LEPA is $389 per acre.

In order to meet the projected irrigation needs (shortages) in Atascosa County, within the Carrizo Aquifer area by year 2010, it would be necessary to install LEPA systems with furrow dikes, or an equivalent conservation method, by year 2010 to approximately 10,005 acres, (28 percent of acres irrigated in year 2000) at a capital cost of approximately $3.89 million, resulting in annual cost per acre-foot of water of $144 (Table 4C.1-16). For Bexar County, 458 of the 7,885 acres irrigated in 2000 would need to be equipped with LEPA at a capital cost of $178 thousand, for an annual cost per acre-foot of $70 (Table 4C.1-16). For Medina County, in order to meet the projected irrigation needs, it would be necessary to equip 18,456 of the 44,755 acres irrigated in year 2000, at a cost of $7.18 million, which when amortized at 6 percent interest rate for 30 years, results in annual cost of water of $112 per acre-foot.

Table 4C.1-16.
Estimated Irrigation Water Conservation Needed and Costs to meet Needs (Shortages) for Counties with Irrigation Needs South Central Texas Water Planning Region

County	Shortage in 2010 (acft)	Irrigation Rate in 2000* (acft/acre)	Water Conservation Potentials 20%** (acft/acre)	Acres Needing Conservation***	Acres Irrigated in 2000	Total Capital Cost ($389/acre)	Annual Cost at 6% per acre-foot	Estimated Cost per acre-foot
Atascosa	1,961	0.98	0.20	10,005	35,796	3,891,985	282,558	144
Bexar	184	2.01	0.40	458	7,885	178,050	12,926	70
Kendall	148	1.27	0.25	583	312	226,661	16,456	111
Medina	4,651	1.26	0.25	18,456	44,755	7,179,520	521,233	112
Zavala	48,165	1.35	0.27	178,389	34,309	69,393,278	5,037,952	105
Atascosa, Bexar, and Medina Subtotal	6,796			28,919	88,436	11,249,555	816,717	120
Total	**55,109**			**207,891**	**123,057**	**80,869,494**	**5,871,125**	**107**

* From Table 4C.1-14.
** Estimated for LEPA and Furrow Dikes.
*** Acres that need to be placed under LEPA and Furrow Dikes to obtain quantities sufficient to meet the projected needs (shortages in 2010 shown in column number 1 of Table 4-1.*****

Given the level of irrigated acres, and irrigation rates for Kendall and Zavala Counties, the LEPA-Furrow Dike irrigation water conservation water management strategy does not accomplish adequate water savings to meet the projected needs; e.g.; Kendall County would need irrigation water conservation on 583 acres, while total irrigated acres in the county in year 2000 was only 312 (Table 4C.1-16). In the case of Zavala County, the projected acreages to which irrigation water conservation would need to be applied is 178,389, while year 2000 irrigated acreage was only 34,309 (Table 4C.1-16). Even though the water conservation strategy would not completely meet the projected needs in Kendall and Zavala Counties, it is recommended that irrigation water conservation be practiced to the extent possible.

In the case of Atascosa, Bexar, and Medina Counties, where the use of LEPA systems with furrow dikes have the potential to reduce irrigation water demands per acre in quantities sufficient to meet the projected needs of 6,796 acft/yr, the estimated annual cost of is $816,717, with a unit cost of $120/acft.

In the discussion above, estimates were presented of the acreages to which water conservation would need to be applied and the quantities of irrigation water conservation needed in order to meet the irrigation water needs (shortages) in Atascosa, Bexar, and Medina Counties. In the following discussion, estimates are presented of the irrigation water conservation potentials in counties with irrigation needs (shortages) in the South Central Texas Water Planning Region (Table 4C.1-17). Based upon estimates that irrigation water conservation practices of LEPA, with Furrow Dikes, can be applied to 75 percent of the acreages that were irrigated in year 2000 in the counties of the region for which water needs have been projected, it is estimated that 23,074 acft/yr of irrigation water conservation can be accomplished at an average cost of $113 per acft (Table 4C.1-17). Of this total, 5,369 acft/yr are in Atascosa County, 2,366 acft/yr are in Bexar County, 8,392 acft/yr are in Medina County, and 6,948 acft/yr are in Zavala County (Table 4C.1-17).

Table 4C.1-17.
Estimated Irrigation Water Conservation Potentials and Costs
For Counties with Irrigation Needs (Shortages)
South Central Texas Water Planning Region

County	*Shortage in 2010 (acft/yr)*	*Irrigation Rate in 2000* (acft/acre)*	*Water Conservation Potentials 20%** (acft/acre)*	*Acres Irrigated in 2000**	*Estimated Acreages to which LEPA & Furrow Dikes Applicable****	*Estimated Water Conservation via LEPA & Furrow Dikes (acft/yr)*	*Total Capital Cost $389/acre (dollars)*	*Annual Cost at 6% for 30 yrs. (dollars)*	*Estimated Cost per acre-foot (dollars)*
Atascosa	1,961	0.98	0.20	35,796	26,847	5,369	10,443,483	758,197	141
Bexar	184	2.01	0.40	7,885	5,914	2,366	2,300,449	167,013	71
Kendall	148	1.27	0.25	312	0	0	0	0	0
Medina	4,651	1.26	0.25	44,755	33,566	8,392	13,057,271	947,958	113
Zavala	48,165	1.35	0.27	34,309	25,732	6,948	10,009,651	726,701	105
Total	**55,109**			**123,057**	**92,059**	**23,074**	**35,810,854**	**2,599,868**	**113**

* From Table 4C.1-14.
** Estimated for LEPA and Furrow Dikes.
*** Estimated that LEPA and Furrow Dikes can be used on 75 percent of acreages irrigated in 2000.

In the case of Kendall and Zavala Counties, it is not economically feasible for agricultural producers to pay for additional water supplies to meet projected irrigation water needs (shortages), even if such supplies were available. For example, in 2004, for irrigated cotton, the estimated income remaining after other production expenses had been paid was about $206 per acre, for grain crops was about $73 per acre, and for vegetables was about $305 per acre.[9] The cost of water from other sources far exceeds these values. For example, cost estimates being made for use in this Regional Water Plan to meet projected municipal needs range from about $432/acft for municipal water conservation, to more than $1,000/acft for water from the Lower Guadalupe for the Bexar county area, and to more than $1,760/acft for desalted seawater for the Bexar County area, and these cost estimates do not include the additional cost of transporting water from these sources to Zavala County.

4C.1.3 Industrial, Steam-electric Power Generation and Mining Water Conservation

In industry, steam-electric power generation, and mining activities water is used for several different purposes, including as an integral part of manufactured products, cleaning and waste removal, waste heat removal, dust control, and landscaping. In the South Central Texas Water Planning Region, the projected need (shortage) of water for manufacturing, steam-electric power generation and mining is 8,493 acft/yr in 2010 and is projected to increase to 70,465 acft/yr in 2060. Water conservation should be considered by industry, steam-electric power generation, and mining water user groups, as a means to meet a part of the projected water needs.

The Water Conservation Implementation Task Force list of Best Management Practices (BMPs) for industry is as follows:[10]

1. Industrial Water Audit;
2. Industrial Water Waste Reduction;
3. Industrial Submetering;
4. Cooling Towers;
5. Cooling Systems Other than Cooling Towers;
6. Industrial Alternative Sources and Reuse of Process Water;
7. Rinsing/Cleaning;

[9] "Crop Enterprise Budgets," Texas Agricultural Extension Service, Uvalde, Texas.
[10] Water Conservation Implementation Task Force, Report to the 79th Legislature, Texas Water Development Board, Special Report, Austin, Texas, November 2004.

8. Water Treatment;
9. Boiler and Steam Systems;
10. Refrigeration (including Chilled Water);
11. Once-through Cooling;
12. Management and Employee Programs;
13. Industrial Landscape; and
14. Industrial Site Specific Conservation.

The BMPs listed above can be expected to improve the efficiency of water use in individual industrial and steam-electric power plants, and mining sites, and/or function as alternative ways to accomplish the purposes for which water is used, and thereby lower the quantity of water that has been projected to be needed by these water user groups. For example, air cooling instead of use of water for cooling in electric power generation and some industrial processes could meet a part of the water needs of these water user group. The collection and use of precipitation runoff at mining sites is a potential way to meet some of the mining water needs, as opposed to drilling wells and/or obtaining water from other sources for dust control and washing purposes. Another source of water for industrial, steam-electric power, and mining is the treatment and reuse of municipal and industrial wastewater.

Although the BMPs listed above, if used by individual establishments of the industrial, steam-electric power, and mining water users of the South Central Texas Region have potentials to meet a part of the projected water needs (shortages), data are not available to the public with which to compute estimates of quantities and costs of these measures.

4C.1.4 Environmental Issues

Municipal water conservation operates to reduce the quantities of water required for a given population, and thereby reduces the quantities of land and other resources needed to supply the population of an individual city with water. For this reason, this water management strategy has little, if any adverse effects upon fish and wildlife habitat, and cultural resources which might otherwise be impacted by development and delivery of the larger quantities of water that would be needed for the lower conservation scenario. However, a potential environmental impact of municipal water conservation might result from reduced quantities of reclaimed water available for established uses, or discharge to streams in the short term. In the South Central Texas Region, significant quantities of the wastewater effluent are being reused for non-potable purposes; therefore, increased municipal water conservation could reduce the quantities of water available for these uses, as well as for discharge to streams in the Region.

The irrigation water conservation methods of this water management option have been developed and tested through public and private sector research, and have been adopted and applied within the Region. Hundreds of LEPA systems have been installed, and are in operation today, and experience has shown that there are not any significant environmental issues associated with this water management strategy. For example, this method improves water use efficiency without making changes to wildlife habitat. This method of application, when coupled with furrow dikes reduces runoff of both applied irrigation water and rainfall. The results are reduced transport of sediment and any fertilizers or other chemicals that have been applied to the crops. Thus, the proposed conservation practices do not have potential adverse effects, and in fact have potential beneficial environmental effects.

In the case of use of BMPs for water conservation in industrial, steam-electric power generation, and mining, the potential improvement in water use efficiencies that result in lower water demands can be expected to reduce the quantities of land and other resources needed to supply water for these purposes.

4C.1.5 Implementation Issues

Demand reduction through water conservation is being implemented throughout the South Central Texas Region (see description of the region). However, the rate of adoption of efficient water-using practices is dependent upon public knowledge of the benefits, information about how to implement water conservation measures, and financing.

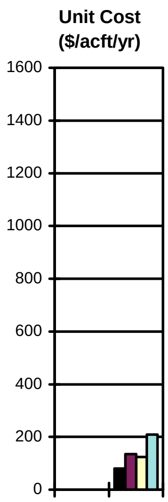
There is widespread public support for both municipal and irrigation water conservation. Cities of the South Central Texas Region have water conservation programs in place. The principal methods of municipal water conservation are public information and education, increasing block water rates, plumbing retrofit, the promotion of low water-using landscapes, and efficient lawn irrigation practices. Irrigation water conservation is being implemented at a steady pace, and as water markets for conserved water expand, this practice will likely reach its maximum potential.

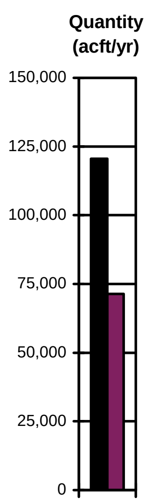
A major barrier to implementation of water conservation in the municipal and irrigation water user groups is financing. Cities can and are giving rebates for plumbing retrofit and the TWDB has low-interest loans for irrigation water conservation equipment. Industry has found water conservation through recycling and reuse to be cost-effective, in that the costs of wastewater treatment are lowered more than enough to pay the recycling and reuse costs.

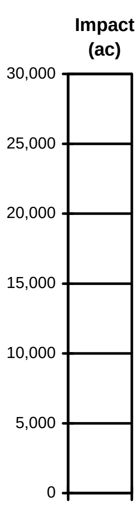
Uncertainty about the effect of demand reduction is present due to the somewhat uncertain rate at which water conservation practices will be implemented, and failure by the public to recognize and realize the magnitude of the water saved and the cost reductions to water users. The implementation of municipal demand reduction will reduce the volume of return flows, creating uncertainty for the planning of reclaimed water treatment facilities, as well as the future availability of return flows for instream flow and freshwater inflow to bays and estuaries.

Industrial, steam-electric power, and mining water conservation through the use of Best Management Practices in these water user groups has potentials to improve water use efficiencies, and thereby contribute to meeting a part of the needs (shortages) projected for these water user groups. However, water conservation in these water user groups will have to be tailored to individual establishments, since each individual water user is a unique factory, power plant, or mining operation.

2006 South Central Texas Regional Water Plan
Water Management Strategy Summary Sheet







Name: Edwards Transfers (L-15)

Description: The Edwards Aquifer Authority Act (SB 1477) regulates the quantity of pumpage from the Edwards Aquifer and establishes a withdrawal permit system which allows an irrigation permit holder to lease up to 50 percent of irrigation permits. This water management strategy considers quantities potentially available for transfer and the associated effects of planned transfers.

***Decade Needed*:** 2000 – 2060

Cost, Quantity of Water, and Land Impacted

Unit Cost of Water:	**$80/$135**	**$/acft/yr**	**Lease Permits: IRP value/firm supply**
	$124/$209	**$acft**	**Buy Permits: IRP value/firm supply.**
Quantity of Water:	**120,479**	**acft/yr**	**Permits at IRP Value**
	71,335	**acft/yr**	**Firm Supply**
Land Impacted:	**0**	**acres**	

Additional Considerations per Regional Water Planning Guidelines

Environmental Factors:
To the extent that the quantities of water transferred are from improved efficiencies in irrigation application methods, there would not be a change in land use, and therefore would not produce environmental effects. Conversion from irrigated to dryland crops would result in changes of vegetation from irrigated to dryland crops. Where lands are converted to grazing and wildlife uses, long-term conservation of soil and natural resources may be increased, due to grass cover versus row crops.

Impacts on Water Resources:
Potential impacts due to pumpage nearer to major springs.

Impacts on Agricultural & Natural Resources:
Voluntary transfers may result in reduced projected irrigation demand/use in source counties.

Other Relevant Factors per SCTRWPG:
SB 1477 restricts transfer via pipeline from Uvalde County. Transfers are subject to critical period and other rules of the Edwards Aquifer Authority.

Comparison of Strategies to Meet Needs:
No significant conflicts with other recommended water management strategies.

Interbasin Transfer Issues:
Not applicable.

Third-Party Impacts of Voluntary Transfers:
Reduction in irrigation lowers demands for farm supply and farm marketing services and support industries thereby reducing local area economic activity. Estimated economic impact of water converted from production of cotton, grain sorghum, wheat and other grains is $448 per acft/yr. For vegetables, the estimated economic impact is $3,378 per acft/yr. The estimates presented here are based upon 2004 farm and purchased input prices, and will change as farm prices change.

Regional Efficiency:
This water management strategy contributes to meeting municipal needs without the construction of traditional water supply facilities.

Water Quality Considerations:
None anticipated.

(This page intentionally left blank.)

4C.2 Edwards Transfers (L-15)

The purposes of this section are to: (1) estimate the quantity of Edwards irrigation water eligible and available for transfer to municipal and industrial use by purchase or lease, and (2) estimate potential impacts of transfers included in the 2006 Regional Water Plan upon the local economies of Uvalde, Medina, and Bexar Counties. This water management strategy is based upon the provisions of Senate Bill 1477 (SB 1477), 1993 Regular Session, Texas Legislature, as amended.

4C.2.1 Provisions for Purchase (or Lease) of Edwards Irrigation Water

SB 1477, Section 1.14, limits the quantity of water that can be withdrawn from the Edwards Aquifer in each calendar year for the period ending December 31, 2007 to no more than 450,000 acft, and for the period beginning January 1, 2008 to no more than 400,000 acft. Section 1.14, Subsection h, specifies that the Edwards Aquifer Authority shall implement and enforce water management practices, procedures, and methods to ensure that, not later than December 31, 2012, continuous minimum springflows at Comal and San Marcos Springs are maintained to protect endangered and threatened species to the extent required by federal law.

Section 1.15 of SB 1477 provides that the Edwards Aquifer Authority shall manage withdrawals and points of withdrawal from the aquifer by granting permits, and Section 1.34 of the Act specifies the manner in which water rights may be transferred, as follows:

> "(a) Water withdrawn from the aquifer must be used within the boundaries of the authority.
>
> (b) The authority by rule may establish a procedure by which a person who installs water conservation equipment may sell the water conserved.
>
> (c) A permit holder may lease permitted water rights, but a holder of a permit for irrigation use may not lease more than 50 percent of the irrigation water rights initially permitted. The user's remaining irrigation water rights must be used in accordance with the original permit and must pass with transfer of the irrigated land."

SB 1477, Section 1.16(e), provides that, "An existing irrigation user shall receive a permit for not less than 2 aft/yr for each acre of land the user actually irrigated in any one calendar year during the historical period."

In accordance with provisions of SB 1477, the EAA has issued Initial Regular Permits (IRPs) for municipal, industrial, and irrigation water use. The total quantity permitted for municipal, industrial, and irrigation uses was 574,234 acft/yr (Table 4C.2-1). The total of the unrestricted transfer potentials for the EAA six-county area is 443,022 acft/yr, of which 285,517 is in Bexar County, 51,744 acft/yr is in Medina County, and 73,400 acft/yr is in Uvalde County (Table 4C.2-1). Of the 443,022 acft/yr of "unrestricted" transferable water rights, the San Antonio Water System (SAWS) has acquired 38,382 acft/yr, leaving 404,640 acft/yr of remaining unrestricted transfer potential, and 131,212 acft/yr of remaining restricted transfer potential (Table 4C.2-1). In the case of "restricted" permits, only the quantity that is saved through irrigation water conservation can be transferred (i.e., that part of the 50 percent of the irrigation permit that by SB 1477 must remain with the land).

Under the provisions of the act allowing for transfer of "restricted" permits, as of June 2005, SAWS has participated in the installation of irrigation water conservation equipment through cost-sharing with the US Department of Agriculture's Environmental Quality Incentives Program (EQIP). Under this irrigation water conservation program, center pivots for irrigation application were installed on approximately 6,000 acres that had previously been irrigated using the flooding application method. It has been estimated that this effort has resulted in about 2,000 acft/yr, of water conservation on the 6,000 acres, and SAWS has applied to the EAA for transfer of the 2,000 acre-feet of irrigation "restricted" permits to municipal and industrial permits.

For Bexar, Medina, and Uvalde Counties, the remaining unrestricted irrigation permit quantity that is potentially available for transfer to municipal and industrial uses is 122,946 acft/yr, and the restricted transfer potential is 128,744 acft/yr (Table 4C.2-1). When adjusted to the 400,000 acft/yr pumping cap and accounting for 15 percent reductions during critical periods, these quantities are 72,795 acft/yr and 76,228 acft/yr, respectively, for unrestricted and restricted permits (Table 4C.2-1).

In the 2006 Regional Water Plan, irrigation transfers are included to meet projected needs of 23 municipal water user groups, in 2010 of 64,312 acft/yr, increasing to 67,834 acft/yr in 2030, and to 71,335 acft/yr in 2060 (quantities are part of the 340,000 acft/yr of firm yield used in the development of the 2006 plan) (Table 4C.2-2). IRP value of permits needed to obtain these quantities of firm yield increase from 108,618 acft/yr in 2010 to 114,566 acft/yr in 2030, and 120,479 acft/yr in 2060 (Table 4C.2-2).

Table 4C.2-1. Edwards Aquifer Water Use Permits by Purpose of Use by County South Central Texas Region

County	*Use Type*	*EAA Initial Regular Permits (acft/yr)*	*Unrestricted Transfer Potential[1] (acft/yr)*	*SAWS Permanent Transfers[2] (acft/yr)*	*Remaining Unrestricted Transfer Potential[3] (acft/yr)*	*400K Cap Drought Supply Equivalent[4] (acft/yr)*	*Remaining Restricted Transfer Potential[5] (acft/yr)*	*400K Cap Drought Supply Equivalent[4] (acft/yr)*
Atascosa	Municipal	259	259	0	259	153	0	0
	Industrial	0	0	0	0	0	0	0
	Irrigation	2,897	1,449	0	1,449	858	1,449	858
	Subtotal	**3,156**	**1,708**	**0**	**1,708**	**1,011**	**1,449**	**858**
Bexar	Municipal	212,006	212,006	548	211,458	125,203	0	0
	Industrial	55,942	55,942	32,037	23,905	14,154	0	0
	Irrigation	35,137	17,569	4,574	12,995	7,694	17,569	10,402
	Subtotal	**303,085**	**285,517**	**37,159**	**248,358**	**147,051**	**17,569**	**10,402**
Comal	Municipal	8,930	8,930	0	8,930	5,287	0	0
	Industrial	10,227	10,227	0	10,227	6,055	0	0
	Irrigation	1,195	598	0	598	354	598	354
	Subtotal	**20,352**	**19,755**	**0**	**19,755**	**11,697**	**598**	**354**
Guadalupe	Municipal	0	0	0	0	0	0	0
	Industrial	253	253	0	253	150	0	0
	Irrigation	0	0	0	0	0	0	0
	Subtotal	**253**	**253**	**0**	**253**	**150**	**0**	**0**
Hays	Municipal	7,265	7,265	0	7,265	4,302	0	0
	Industrial	2,959	2,959	0	2,959	1,752	0	0
	Irrigation	845	423	0	423	250	423	250
	Subtotal	**11,069**	**10,647**	**0**	**10,647**	**6,304**	**423**	**250**
Medina	Municipal	6,126	6,126	0	6,126	3,627	0	0
	Industrial	1,258	1,258	0	1,258	745	0	0
	Irrigation	88,720	44,360	940	43,420	25,709	44,360	26,265
	Subtotal	**96,104**	**51,744**	**940**	**50,804**	**30,081**	**44,360**	**26,265**
Uvalde	Municipal	4,626	4,626	0	4,626	2,739	0	0
	Industrial	1,959	1,959	0	1,959	1,160	0	0
	Irrigation	133,630	66,815	284	66,532	39,393	66,815	39,561
	Subtotal	**140,215**	**73,400**	**284**	**73,117**	**43,292**	**66,815**	**39,561**
Bexar, Medina, and Uvalde Counties Subtotals								
	Municipal	**222,758**	**222,758**	**548**	**222,210**	**131,569**	**0**	**0**
	Industrial	**59,159**	**59,159**	**32,037**	**27,122**	**16,059**	**0**	**0**
	Irrigation	**257,487**	**128,744**	**5,798**	**122,946**	**72,795**	**128,744**	**76,228**
	Subtotal	**539,404**	**410,661**	**38,382**	**372,278**	**220,423**	**128,744**	**76,228**
Edwards Aquifer Area Totals								
	Municipal	**239,212**	**239,212**	**548**	**238,664**	**141,311**	**0**	**0**
	Industrial	**72,598**	**72,598**	**32,037**	**40,561**	**24,016**	**0**	**0**
	Irrigation	**262,424**	**131,212**	**5,798**	**125,415**	**74,257**	**131,212**	**77,690**
	EAA Total	**574,234**	**443,022**	**38,382**	**404,640**	**239,585**	**131,212**	**77,690**

[1] Calculated as 50% of irrigation and 100% of municipal & industrial Initial Regular Permit amounts.
[2] Provided by SAWS in March 2004.
[3] Unrestricted transfer potential net of SAWS permanent transfers.
[4] Calculated as 85% of transfer potential after pro-ration of Initial Regular Permits to a 400,000 acft/yr cap.
[5] Maximum amount potentially transferable with conversion of base to unrestricted irrigation groundwater by installation of water conservation equipment.

Table 4C.2-2.
Edwards Aquifer Water Transfers by County
South Central Texas Region

Entity	County	Year 2010 (acft)	2020 (acft)	2030 (acft)	2040 (acft)	2050 (acft)	2060 (acft)
Lytle	Atascosa	196	207	217	224	234	243
Subtotal		196	207	217	224	234	243
Alamo Heights	Bexar	515	578	580	576	590	614
Atascosa Rural WSC	Bexar	561	732	884	1,011	1,121	1,233
Kirby	Bexar	299	298	301	295	307	328
Lackland AFB (CDP)	Bexar	857	833	809	785	769	769
Shavano Park	Bexar	499	515	527	536	548	560
Universal City	Bexar	141	449	708	658	634	634
Water Ser Inc (Apex Water Ser)	Bexar	908	1,145	1,381	1,596	1,798	2,015
Subtotal		3,780	4,550	5,190	5,457	5,767	6,153
Garden Ridge	Comal	115	171	234	298	364	436
Subtotal		115	171	234	298	364	436
Crystal Clear WSC (Meet part of Need)	Guadalupe	1,200	1,400	1,400	1,400	1,400	1,400
Green Valley SUD (Meet part of Need)	Guadalupe						
Subtotal (Crystal Clear & Green Valley)		1,200	1,400	1,400	1,400	1,400	1,400
County Line WSC (Meet Part of Need)	Hays	1,000	1,000	1,000	1,000	1,000	1,000
Subtotal		1,000	1,000	1,000	1,000	1,000	1,000
Castroville	Medina	274	337	396	448	502	555
East Medina SUD	Medina	0	0	95	184	278	372
Hondo	Medina	804	1,021	1,225	1,395	1,568	1,737
La Coste	Medina	96	113	130	142	156	172
Natalia	Medina	198	242	283	318	353	387
Yancey WSC	Medina	577	758	925	1,073	1,214	1,348
County-Other	Medina	180	507	799	1,058	1,326	1,567
Subtotal		2,129	2,978	3,853	4,618	5,397	6,138
Sabinal	Uvalde	139	135	130	125	121	121
Uvalde	Uvalde	3,793	3,830	3,850	3,854	3,856	3,884
Subtotal		3,932	3,965	3,980	3,979	3,977	4,005
Subtotals		12,352	14,271	15,874	16,976	18,139	19,375
SAWS		48,000	48,000	48,000	48,000	48,000	48,000
BMWD		3,960	3,960	3,960	3,960	3,960	3,960
TOTAL Firm Supply (340,000 acft/yr)		**64,312**	**66,231**	**67,834**	**68,936**	**70,099**	**71,335**
IRP Value Permits Needed*	1.6889	108,618	111,859	114,566	116,428	118,392	120,479

*IRP value of permits needed is 574,234/340,000 times firm supply needed.

Given the quantities of transfers, as shown in Table 4C.2-2, the quantities of projected irrigation surpluses, irrigation water conservation potentials, and quantities of irrigation water conservation needed to meet projected irrigation needs in Bexar, Medina, and Uvalde Counties (Table 4C.2-3), there is a projected transfer of irrigation water to municipal and industrial uses in

Table 4C.2-3.
Summary of Sources of Edwards Aquifer Water for Transfer
South Central Texas Region

Source of Supply	Year					
	2010 (acft)	**2020 (acft)**	**2030 (acft)**	**2040 (acft)**	**2050 (acft)**	**2060 (acft)**
Irrigation Surpluses						
Bexar County	6,853	7,446	7,447	7,999	8,527	9,034
Medina County	-30	2,113	4,163	6,128	8,010	9,814
Uvalde County	24,246	26,438	28,534	30,549	32,484	34,344
Subtotal	31,069	35,997	40,144	44,676	49,021	53,192
Irrigation Water Conservation Potentials						
Bexar County	2,366	2,366	2,366	2,366	2,366	2,366
Medina County	8,392	8,392	8,392	8,392	8,392	8,392
Uvalde County	8,442	8,442	8,442	8,442	8,442	8,442
Subtotal	19,200	19,200	19,200	19,200	19,200	19,200
Irrigation Water Conservation to Meet Needs						
Bexar County	529	529	529	529	529	529
Medina County	4,651	2,887	1,200	0	0	0
Uvalde County	0	0	0	0	0	0
Subtotal	5,180	3,416	1,729	529	529	529
Total Available						
(Surpluses + Cons Potential - Cons to Meet Needs)	45,089	51,781	57,615	63,347	67,692	71,863
Firm Supply Transfers	64,312	66,231	67,834	68,936	70,099	71,335
Change in Supply for Irrigation *	-19,223	-14,450	-10,219	-5,589	-2,407	528
Projected Irrigation Demand						
Bexar County	15,273	14,628	14,010	13,417	12,850	12,306
Medina County	54,450	52,179	50,005	47,922	45,927	44,015
Uvalde County	55,791	53,609	51,513	49,498	47,563	45,703
Subtotal	125,514	120,416	115,528	110,837	106,340	102,024
Transfer as Percent of Projected Irrigation Demand	15.32%	12.00%	8.85%	5.04%	2.26%	0.52%

* Irrigation surpluses plus irrigation conservation potentials minus irrigation conservation to meet projected needs minus Firm Supply Transfers equals net quantities of transfers from irrigation to municipal uses.

Bexar, Medina, and Uvalde Counties of 19,223 acft/yr in 2010, 10,219 acft/yr in 2030, 2,407 acft/yr in 2050, and surplus of 528 acft/yr in 2060 (Table 4C.2-3); e.g.; the Edwards transfer water management strategies of the 2006 Regional Water Plan result in transfers of projected irrigation water surpluses, a part of the quantities of irrigation water conservation, and water that was projected to be used in irrigation in the quantities shown in Table 4C.2-3. The quantity that would be transferred from irrigation uses is 15.32 percent of the projected irrigation demand in 2010, 8.85 percent in 2030, and 2.26 percent in 2050 (Table 4C.2-3). In 2060, there is an estimated 528 acft/yr of unused irrigation water that is not projected to be transferred (Table 4C.2-3).

4C.2.2 Edwards Aquifer Irrigation Water Supply and Water Cost Information

In the Edwards Aquifer area, irrigation with water from the aquifer and from the Medina Lake System supplements annual precipitation, which averages 25 inches in the west and 28 inches in the east.[1] The quantity of irrigation water applied per acre can vary from a few inches when precipitation is above average to as much as 42 inches on some high water demand crops during drought years.

Water from the Edwards Aquifer is used in Bexar, Medina, and Uvalde Counties for irrigation of crops such as corn, cotton, grain sorghum, wheat, vegetables, and forage for livestock. Although cotton, corn, grain sorghum, wheat and forage for livestock, can be produced in Bexar, Medina, and Uvalde Counties without irrigation, the yields per acre are only about one-third to one-half those on irrigated acres (Table 4C.2-4). In the case of vegetables and oil seed crops, dryland production is not possible in most years. Thus, without a supply of irrigation water, the total value of agricultural commodities marketed in this part of the South Central Texas Region would be reduced, and agricultural marketing establishments' business levels could be lowered.

Average annual irrigated acreage in the Bexar, Medina, and Uvalde Counties area for the 1996 through 2000 period was approximately 104,022 acres, with average annual irrigation water use of 170,746 acft, of which approximately 122,100 acft/yr was from the Edwards Aquifer (Table 4C.2-5).[2] Of total water use of 170,746 acft/yr, approximately 7.9 percent was

[1] Texas Department of Water Resources, "Climatic Atlas of Texas," LP-192, December 1983.

[2] "Edwards Aquifer Authority Hydrologic Data Report for 2003," Edwards Aquifer Authority, San Antonio, Texas, June 2004.

applied to cotton, 8.3 percent was used for the production of Grain Sorghum, 48.62 percent was used to grow corn, 6.19 percent was used to produce wheat and other small grains, 11.23 percent was used to grow hay, forage, and pasture, 11.67 percent was used to produce vegetables, and 6.09 percent was used for all other crops (Table 4C.2-5).

Table 4C.2-4
Dryland and Irrigated Crop Yields*
Bexar, Medina and Uvalde Counties
South Central Texas Region

Crop	*Dryland*	*Irrigated*
Corn	60 bu/acre	115 bu/acre
Cotton	350 lbs/acre	960 lbs/acre
Grain Sorghum	3,000 lbs/acre	5,000 lbs/acre
Guar	800 lbs/acre	1,850 lbs/acre
Peanuts	**	3,500 lbs/acre
Sesame	**	1,250 lbs/acre
Winter Wheat/Grain	20 bu/acre	40 bu/acre
Winter Wheat/Grazing	45 days/acre	90 days/acre
Spring Wheat/Grain	10 bu/acre	50 bu/acre
Beets/Processing	**	14 tons/acre
Cabbage	**	16 tons/acre
Cantaloupe	**	300 cartons/acre
Carrots/Fresh	**	12 tons/acre
Carrots/Processing	**	14 tons/acre
Cucumbers/Fresh	**	6.25 tons/acre
Cucumbers/Pickles	**	8 tons/acre
Lettuce	**	12.5 tons/acre
Onions	**	18.75 tons/acre
Spinach/Fresh	**	450 bu/acre
Spinach/Processing	**	11 tons/acre
Forage		
Coastal Bermuda/Pasture	200 days/acre***	600 days/acre***
Coastal Bermuda/Hay	**	10 tons/acre
Forage Sorghum/Grazing	**	600 days/acre***
Forage Sorghum/Hay	4.5 tons/acre	10 tons/acre

*Source: “Texas Crop Enterprise Budgets, Southwest Texas District;” Peña, Jose G.; Texas Agricultural Extension Service, Texas A&M University System; Uvalde, Texas, 1997. The yields per acre listed here are indications of potential yields for high level farm and ranch management and favorable weather conditions, as opposed to projections of yields for average conditions.

** Not produced dryland.

*** May stock more than one animal unit per acre.

Table 4C.2-5.
Estimated Differences between Dryland and Irrigated Income and Costs of Purchased Inputs*
Bexar, Medina, and Uvalde Counties
South Central Texas Region

Major Crop Irrigated	Acres Irrigated 1996--2000** Average	Percent of Total Acres (%)	Irrigation Water Applied **		Total Income per Acre		Purchased Inputs per Acre		Difference per Acre		Region Difference Total		Irrigation Water Used (%)
			(acft)	(acft/acre)	Dryland (dollars)	Irrigated (dollars)	Dryland (dollars)	Irrigated (dollars)	Income (dollars)	Inputs (dollars)	Income (dollars)	Inputs (dollars)	
Field Crops													
Cotton	7,717	7.42	13,503	(1.75)	270	811	248	590	541	342	4,175,005	2,639,282	7.91
Grain Sorghum	10,788	10.37	14,168	(1.31)	142	308	122	207	166	85	1,790,742	916,946	8.30
Corn	48,060	46.20	83,017	(1.73)	165	342	142	266	177	124	8,506,620	5,959,440	48.62
Wheat & Other Grain	9,796	9.42	10,570	(1.08)	140	220	88	157	80	69	783,680	675,924	6.19
Subtotal	76,361	73.41	121,258	(1.59)	169	369	143	276	200	133	15,256,047	10,191,592	71.02
Hay, Forage & Past[1]	10,431	10.03	19,180	(1.84)	167	553	174	457	386	283	4,026,212	2,951,860	11.23
Subtotal (Field & Forage)	86,792	83.43	140,438	(1.62)							19,282,258	13,143,452	82.25
Vegetables													
Shallow Rooted[2]	6,387	6.14	9,472	(1.48)	***	3,560	***	2,944	3,560	2,944	22,737,008	18,802,739	5.55
Deep Rooted[3]	6,849	6.58	10,446	(1.53)	***	1,068	***	760	1,068	760	7,314,305	5,204,936	6.12
Subtotal Vegetables	13,236	12.72	19,918	(1.50)					2,271	1,814	30,051,313	24,007,675	11.67
All Other Crops	3,995	3.84	10,390	(2.60)	***	772	***	264	772	264	3,084,294	1,054,733	6.09
Total for All Crops	104,022	100.00	170,746	(1.64)							52,417,866	38,205,860	100.00

* Source: "Texas Crop Enterprise Budgets, Southwest Texas District," Peña, Jose G.: Texas Agricultural Extension Service, Texas A&M University System, Uvalde, Texas , 2004. All income and input dollars are in 2004 prices.

** Annual Irrigation Surveys, Texas Water Development Board, Austin, Texas. For the 1996 through 2000 period, according to the EAA Hydrologic Data Report of 3003, average annual irrigation water use from the Edwards Aquifer was 122,100 acre-feet per year. The total Edwards Aquifer water use for Bexar, Medina, and Uvalde Counties in year 2000 was reported at 78,600 acre-feet.

1 Coastal Bermuda, Alfalfa, and Forage Sorghum.

2 Shallow Rooted Vegetables (cabbage, lettuce, onions, and spinach).

3 Deep Rooted Vegetables (beets, cantaloupes, carrots, and cucumbers).

*** Not produced dryland.

4C.2.3 Regional Economic Effects of Edwards Irrigation Water Transfer

Any reduction in irrigation that would occur due to lease or sale of Edwards Aquifer irrigation permits would result in reduced value of production of crops, that in turn would result in reduced demand for agricultural production inputs and agricultural marketing and processing services, and of course, farm incomes would be lower. Reduced irrigation would result in lower irrigated agriculture purchases of production inputs from other sectors of the economy, including seed, fertilizer, herbicides, insecticides, fuel, machinery, equipment, labor, transportation, and financial and business services. In addition, of course, there would be less grain, fiber, and vegetables sold to the agriculture processing sectors, thereby reducing business for the agricultural marketing, food and fiber processing, transportation, storage, warehousing, and related non-farm sectors of the economy. These economic impacts associated with reductions in irrigation are estimated below.

The sale or lease of irrigation permits for which the water is used to produce cotton, grain sorghum, and wheat and other grain, with the acreage affected being converted to dryland production of the same crops, would reduce gross farm income by $200 per acre and reduce purchased inputs by $133 per acre of irrigated land for which the irrigation water is sold or leased. On a per acre-foot of water basis, the farm income effect is $126, and the purchased inputs effect is $84. (The computations are from data in Table 4C.2-5 and are as follows: regional difference between irrigation and dryland income for cotton, grain sorghum, corn and wheat and other grains is $15,282,047; regional difference in purchased inputs is $10,191,592, and quantity of irrigation water is 121,258 acft. $15,282,047 ÷ 121,258 = $126 per acft for the income effect, and $10,191,592 ÷ 121,258 = $84 for the purchased inputs effects.)

The total output multiplier for crop production in the region is estimated at 2.24, which means that for each dollar of crop value at the farm, the total business effect within the area is $2.24.[3] Given this multiplier, the impact of a change of 1 acft in irrigation water use to produce cotton, grain sorghum, and wheat and other grains has an estimated economy-wide business effect of $448 per acft/year ($200 per acft x 2.24 = $448).

[3] Unpublished Output Multipliers; Lonnie L. Jones, Ph.D., Department of Agricultural Economics, Texas A&M University, College Station, Texas, April 1994.

In the case of vegetable production, the gross income effect per acft of water used is $1,508 per year (Table 4C.2-5), resulting in an estimated economy-wide business effect of $3,378 per acft/yr ($1,508 per acft x 2.24 = $3,378), of which $1,508 is the farm value and $1,870 is the off-farm gross business value.

The estimated farm income effect of the projected transfer of water from irrigation to municipal and industrial uses is estimated at $2.42 million per year in 2010, $1.29 million per year in 2030, and $0.30 million per year in 2050 (Table 4C.2-6). The reduction in value of purchased inputs in 2010 is $1.61 million per year, $0.89 million per year in 2030, and $0.20 million per year in 2050 (Table 4C.2-6). The total economic impact of the transfers is estimated at $5.42 million annually in 2010, $2.88 million in 2030, and $0.68 million annually in 2050 (Table 4C.2-6).

Recently, sales and leases of irrigation IRPs for municipal and industrial use have been made, with lease rates for 5 to 20 year terms at rates of $77/acft/yr to $83/acft/yr. In 2004, fee simple purchase price of Edwards IRPs has been in the range of $1,650 to $1,750 per acre foot.4 An IRP lease price of $80/acft/yr is equivalent to a firm supply lease price of $135/acft/yr ($80 x 574,234/340,000). Similarly, an IRP purchase price of $1,700/acft amortized at 6 percent interest for 30 years is equivalent to a firm supply purchase price of $209/acft/yr ($1,700 x 0.07265 x 574,234/340,000). Cost estimates for Edwards Transfers in the 2006 regional plan are based on the lease price of $135/acft/yr. The annual cost of planned firm supply transfers of 71,335 acft/yr is estimated at $9,630,225.

4C.2.4 Environmental Issues

The primary environmental concerns associated with Edwards Irrigation Transfers are the conversion of irrigated land to dryland crops or grassland, or a combination of dryland crops and grassland. Since both dryland crop and range grasslands are present within the area, demonstrating that dryland and range grasslands are possible for the region, the major concern is with establishment of vegetation upon acreages to be returned to grassland or range vegetation. An additional concern involves potential reductions in discharge at Comal and San Marcos Springs associated with increased pumpage from municipal wells closer to the springs.

[4] Actual prices paid by San Antonio Water System in 2004, San Antonio Texas, 2005.

Table 4C.2-6
Estimated Economic Effects of Irrigation Water Transfer
Bexar, Medina and Uvalde Counties
South Central Texas Region

Factors	Units	Year					
		2010	2020	2030	2040	2050	2060
Irrigation Transfers (Unused Irrigation)*	Acre-Feet	19,223	16,350	10,219	5,589	2,407	0
Economic Effects Per Unit							
Farm Income Per Acre-Foot	Dollars	126	126	126	126	126	126
Purchased Inputs Per Acre-Foot	Dollars	84	84	84	84	84	84
Total Output Multiplier	Dollars	2.24	2.24	2.24	2.24	2.24	2.24
Regional Economic Effects							
Total Farm Income	Million Dollars	2.42	2.06	1.29	0.70	0.30	0.00
Total Purchased Inputs	Million Dollars	1.61	1.37	0.89	0.47	0.20	0.00
Total Economic Impact	Million Dollars	5.42	4.61	2.88	1.58	0.68	0.00

* Irrigation surpluses plus irrigation conservation potentials minus irrigation conservation to meet projected needs minus Firm Supply Transfers equals net quantities of transfers from irrigation to municipal and industrial uses (Table 4C.2-3).

It is expected that dryland crop production can be carried out on acreages that were previously irrigated. However, fallow farmland to be converted to grassland with no native grass plantings could become infested with opportunistic weeds, followed by slower growing native thornbrush plants characteristic of the surrounding unimproved rangelands. Recovery of the land could take two decades or more, depending on use for cattle grazing and brush management practices. These lands, along with lands converted to improved rangeland, would eventually provide additional native species habitat. A program of converting cropland to native grasses would speed the process of reaching a mature native plant community and reduce the opportunity for soil erosion through water and winds. Such a program could provide habitat for native Texas wildlife, including the horned toad, tortoises, deer, hawks, and other dessert grassland species. The cost of seeding is not included in the purchase or lease price of the water.

No impacts to cultural resources are anticipated since this strategy does not involve construction.

4C.2.5 Water Quality and Treatability

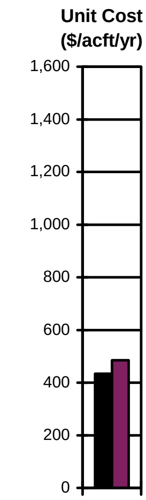
No change is expected in water quality, since this water management strategy would reduce pumpage of Edwards Water for irrigation and allow equivalent quantities to be pumped for municipal and industrial purposes.

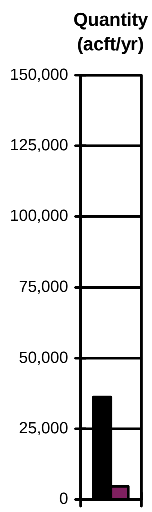
4C.2.6 Implementation Issues

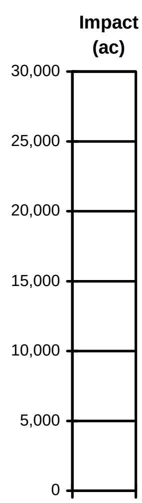
The leasing and purchasing of Edwards Irrigation Water for municipal and industrial uses is being done to at the present time. Further implementation of this strategy will involve:

1. Willingness of Edwards Irrigation Permit holders to sell or lease permits issued for irrigation.
2. Approval by EAA of permit transfer and/or leases and compliance with critical period and other rules of the EAA.
3. Further evaluation of potential economic effects associated with the conversion from irrigated to other types of land use.
4. Further evaluation of potential effects of relocation of pumpage centers on discharges from Comal and San Marcos Springs and/or on species dependent upon Edwards Aquifer or spring habitats.

2006 South Central Texas Regional Water Plan
Water Management Strategy Summary Sheet







Name: ***Recycled Water Programs***

Description: Phased expansion of the existing SAWS Recycled Water Program to include north and south interconnections between the two main legs of the existing system, tie-in to the Dos Rios Water Recycling Center, and extension of existing lines to reach additional customers (36,258 acft/yr in 2060). Strategy also includes recommended uses of recycled water in Comal, Guadalupe, and Hays Counties for non-potable purposes (4,600 acft/yr in 2060).

***Decade Needed*:** 2000 - 2060

Cost, Quantity of Water, and Land Impacted

Unit Cost of Water:	**$434 & $485**	**$/acft/yr**	**Treated Water Delivered**
Quantity of Water:	**36,258 & 4,600**	**acft/yr**	**Reliability = Firm**
Land Impacted:	**N/A**	**acres**	

Additional Considerations per Regional Water Planning Guidelines

Environmental Factors:
Ultimate configuration for a phased expansion of the SAWS Recycled Water Program has yet to be determined. It is likely that further expansion of the water recycling system will encounter similar environmental issues and concerns to those of the existing system. Pipelines could traverse Black-capped Vireo or Golden-cheeked Warbler habitat.

Impacts on Water Resources:
Effluent discharges (net of recycled water program expansion) are likely to increase throughout the planning period.

Impacts on Agricultural & Natural Resources:
Implementation will occur in predominantly urban areas and likely be concentrated in existing utility easements and previously disturbed floodplains. Hence, impacts to agricultural and natural resources are expected to be minimal.

Other Relevant Factors per SCTRWPG:
Encourages beneficial use of available resource.

Comparison of Strategies to Meet Needs:
Relatively low unit cost. No conflicts with other recommended water management strategies.

Interbasin Transfer Issues:
Not applicable.

Third-Party Impacts of Voluntary Transfers:
Not applicable.

Regional Efficiency:
New supply proximate to points of need.

Water Quality Considerations:
At current levels of treatment, recycled water must be used for non-potable purposes only.

(This page intentionally left blank.)

4C.3 Recycled Water Programs

4C.3.1 Description of Water Management Strategy

The Recycled Water Programs water management strategy involves expansion of programs that reclaim municipal wastewater for non-potable uses such as irrigation of golf courses, parks, and open spaces of cities, landscape watering of large office and business complexes, cooling of large office and business complexes, steam-electric power plant cooling, process or wash water for mining operations, irrigation of farms that produce livestock feed and forage, irrigation of farms that produce sod, ornamentals, and landscape plants, and for instream uses such as riverwalks and waterways. This strategy is being used within the region by entities including SAWS, SARA, New Braunfels Utilities, the City of Seguin and the City of San Marcos and can be expanded as the quantities of municipal wastewater increase with population growth. An advantage of this strategy is that the water has already been developed and brought to the locations of many of the uses listed above. The phased expansion of the SAWS Recycled Water Program is described and evaluated below as a water management strategy to meet a part of the projected water needs of WUGs in Bexar County. In addition, information is provided about projected quantities and unit costs of recycle water for use in Comal, Guadalupe, and Hays Counties.

The San Antonio electric utility, City Public Service (CPS), has been using reclaimed wastewater for electric power generation for decades, and during the 1990s, the San Antonio Water System (SAWS) developed a Reuse Water Program.[1,2] Phase I includes two main conveyance lines, with one line beginning at the Salado Creek Water Recycling Center (WRC) and extending north through the eastern part of the city, and the other beginning at the Leon Creek WRC and extending north through the western part of the city (Figure 4C.3.-1). Phase II of the Plan provides for interconnection of these two conveyance lines to allow east-west as well as north-south flow of recycle water. Subsequent expansion of the system may provide additional water supply to other parts of the city and Bexar County[3].

[1] San Antonio Water System, "San Antonio Water System, Water Conservation and Reuse Plan," November 1998.
[2] Pape-Dawson Engineers, Inc., "Environmental Assessment System Interconnect Addendum," San Antonio Water System, September 2000.
[3] US Bureau of Reclamation, "Reuse Water Storage Alternatives Assessment Report," San Antonio Water System, September 2000.

The present SAWS Recycled Water Program is capable of delivering about 35,000 acft/yr, with estimated consumptive reuse of 24,941 acft/yr, which is included as existing water supply of the South Central Texas Region. Recycled Water is used for non-potable purposes, including industrial purposes, office and business cooling towers, landscape irrigation, and streamflow augmentation. Such uses are direct substitutes for water previously obtained from the Edwards Aquifer, and thereby reduce the use of Edwards Aquifer water by the quantity of recycled water used. This water management strategy involves the expansion of the recycled water program to provide dependable water supplies for non-potable uses, bringing the total supply of recycled water in 2010 to a level sufficient to meet 20 percent of SAWS projected municipal and industrial water demands for the 2010 through 2060 projection period. A portion of the Southern Interconnection between Salado WRC and Dos Rios WRC has been completed. Facilities for future expansion are expected to include Southern Interconnections between the Leon Creek and Dos Rios WRCs as well as a Northern Interconnection linking the transmission lines originating at the Leon Creek and Salado Creek WRCs (Figure 4C.3-1).

4C.3.2 Water Availability

Increased treated wastewater volumes associated with increased municipal water use are potential sources of water to meet a part of the projected non-potable needs (shortages) of the SAWS service area.4 This reuse by SAWS may be accomplished directly (prior to stream discharge or "flange-to-flange") or indirectly through bed and banks delivery to downstream diversion and/or storage sites, subject to applicable law. Direct and indirect reuse methods are both currently used by SAWS. However, it is most likely that direct reuse methods will be used in the expansion of the recycled water program, since indirect reuse of treated wastewater volumes derived from privately owned groundwater and/or interbasin transfer of surface water may be subject to fewer water rights or environmental flow constraints because these sources would not naturally have been present in the streams below wastewater treatment facilities.

For the purposes of consideration for inclusion in the South Central Texas Regional Water Plan, future expansion of SAWS Recycled Water Program is based on the goal of meeting 20 percent of projected municipal and industrial water demands with recycled water. The

[4] Recycled water is also included in the plan for steam-electric power, mining, and non-potable municipal uses in Hays, Guadalupe, and Comal Counties (see Section 4B.1).

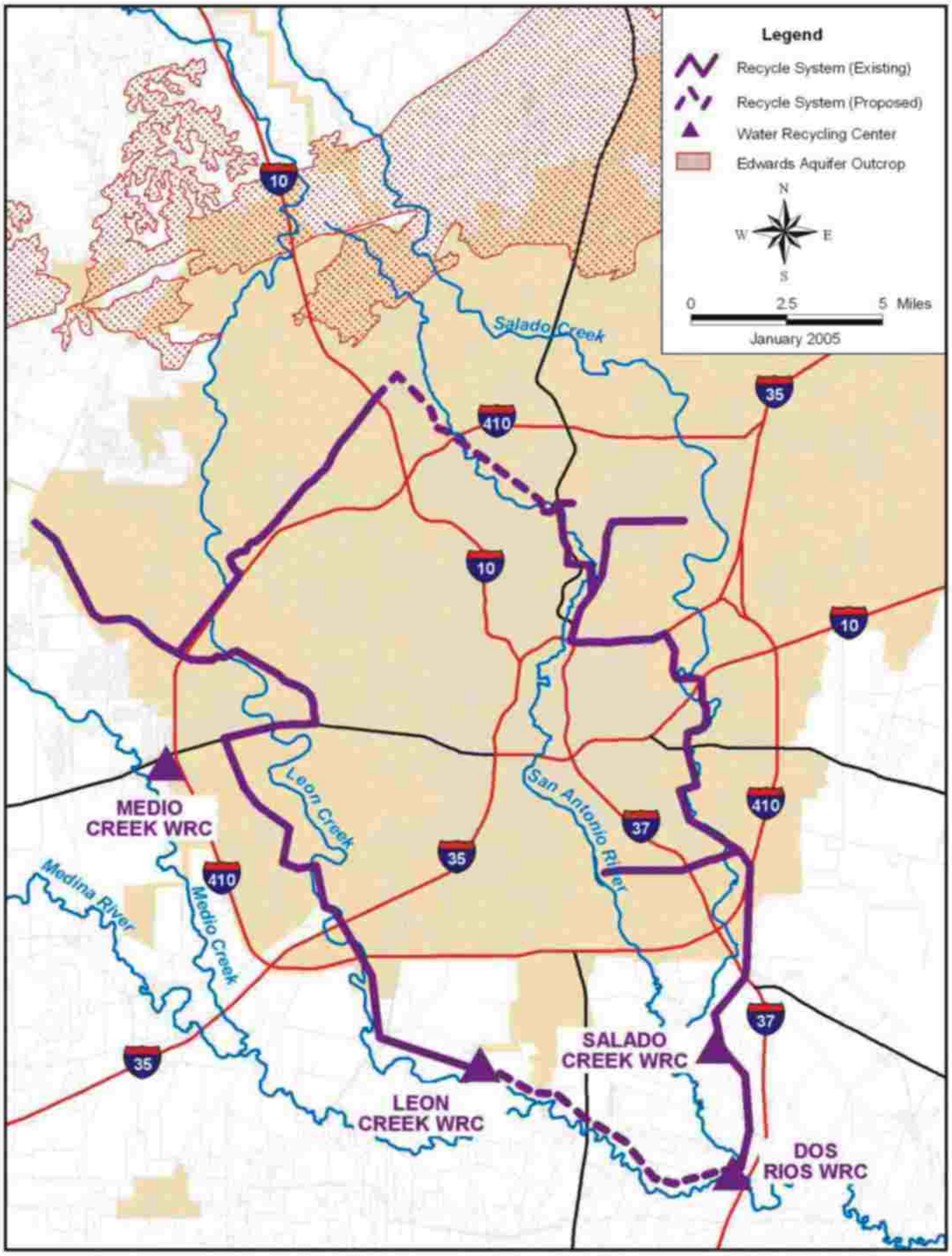


Figure 4C.3-1. Map of City of San Antonio Showing Phases I and II of Recycle Program

estimated future quantities of recycled water potentially available for use in San Antonio, after adjusting projected demands to account for recommended municipal water conservation projections for San Antonio (Section 4C.1.1, Table 4C.1-10, Vol. II), increase from 18,712 acft/y in 2010 to 36,258 acft/yr in 2060 (Table 4C.3-1). The projected remaining effluent, after accounting for quantities of use by SAWS recycle programs that is likely to be discharged to the San Antonio River and/or tributary streams increases from 65,479 acft/yr in 2010 to 91,798 acft/yr in 2060 (Table 4C.3-1). These projected effluent volumes will be available for downstream water rights, reclamation through bed and banks transfer, and instream uses.

The projected quantities of potentially available recycle water for industrial, steam-electric power generation and mining uses in Comal, Guadalupe, and Hays Counties increase from 587 acft/y in 2010 to about 4,600 acft/yr in 2060.

Table 4C.3-1.
Estimated Potential Quantities of Recycled Water[1]
San Antonio Water System

	2000 acft	2010 acft	2020 acft	2030 acft	2040 acft	2050 acft	2060 acft
Projected Demand							
Municipal	172,815	198,065	220,078	241,043	256,842	272,214	287,593
Industrial	21,252	25,951	29,497	32,775	36,068	38,965	42,112
Conservation (-)		5,752	7,318	8,795	10,490	15,698	23,711
Net Projected Demand[2]	194,067	218,264	242,257	265,023	282,420	295,481	305,994
Estimated Total Effluent[3]	116,440	130,958	145,354	159,014	169,452	177,289	183,596
Current Recycle Quantities[4]	24,941	24,941	24,941	24,941	24,941	24,941	24,941
Future Recycle Quantities		18,712	23,510	28,064	31,543	34,155	36,258
Total Recycle Goal[5]	38,813	43,653	48,451	53,005	56,484	59,096	61,199
Remaining Effluent	77,627	87,306	96,903	106,009	112,968	118,192	122,398

[1]All quantities in acre-feet per year.

[2] SAWS municipal demand plus Bexar County industrial demand less municipal water conservation projections for SAWS.

[3] Calculated as 60 percent of Net Projected Demand.

[4] Quantity shown is estimated consumptive use of recycled water. System capacity is about 35,000 acft/yr.

[5] Calculated as 20 percent of Net Projected Demand.

4C.3.3 Environmental Issues

It is likely that further expansion of the water recycling system will encounter environmental issues and concerns similar to those encountered in the implementation of the existing system. Expansion of the SAWS Recycled Water Program will occur within Bexar County, which lies at the junction of the Edwards Plateau (thin, rocky soils), Blackland Prairie (thick, clayey soils), and Rio Grande Plains (sandy soils) physiographic provinces. Bexar County is drained by tributaries of the Medina and San Antonio Rivers and underlain by the Edwards Aquifer from which San Antonio and San Pedro Springs periodically emanate. Flora and fauna of Bexar County are representative of the Edwards Plateau, Blackland Prairie, and South Texas Plains vegetation areas. Urban and agricultural development within the county have had an influence on native terrestrial, riparian, and aquatic biota and have created cultural resources of historical, archaeological, and socio-economic importance.

As indicated in Table 4C.3-1, treated effluent quantities in excess of those planned to be recycled are expected to increase throughout the 50-year planning horizon as a result of increasing water use and development of new water supplies from downstream, out-of-basin, and/or groundwater sources. Hence, downstream flows in the San Antonio River are expected to increase over time, potentially resulting in improved reliability of existing water rights, enhanced instream uses, and additional freshwater inflows to the Guadalupe Estuary.

Applicable regulations define three classifications of recycled water based on the level of water quality as reflected in measurable parameters including BOD5, turbidity, and fecal coliform. SAWS expects to utilize only Type I recycled water which is of high quality and can be used in areas where the likelihood of public contact may be high. Non-food crops and landscaped areas may be irrigated using Type I recycled water without restriction, however, food crops so irrigated must be processed prior to human consumption. Water produced by the Salado, Leon, and Dos Rios Water Recycling Centers presently complies with the specified quality parameters for Type I recycled water. Significant environmental impacts from the expanded reuse program are more likely to arise from utility construction than from the quality of the recycled water.

Implementation of an expanded distribution system for recycled water will occur in predominantly urban areas and likely be concentrated in existing utility easements and previously disturbed floodplains. Evaluations of new utility easements and stream crossings for potential impacts to endangered species or unique habitats prior to clearing or construction will provide the information needed to avoid those impacts.

Endangered species listed for Bexar County (Table 4C.3-2) include the Black-capped Vireo, Golden-cheeked Warbler, two migratory bird species, six arachnids, and three beetles. Some care may be necessary should recycled water pipelines traverse preferred habit for these endemic species. Black-capped Vireos are insectivorous songbirds that nest in low shrubland.

Thickets where vegetation extends to ground level. Golden-cheeked Warblers prefer habitat consisting of mature oak-juniper woodlands located along steep escarpments and canyons. The listed invertebrate species (arachnids and beetles) are all endemic to karst features or caves located in north and northwest Bexar County. The listed migratory bird species tend to avoid areas of concentrated human development.

Cultural resources protection on public lands in Texas is afforded by the Antiquities Code of Texas (Title 9, Chapter 191, Texas Natural Resource Code of 1977), the National Historic Preservation Act (Pl96-515), and the Archeological and Historic Preservation Act (PL93-291). Based on the review of available records housed at the Texas Archeological Research Laboratory in Austin, eight cultural resource sites appear to occur within the proposed project area. Table 4C.3-3 lists the archeological sites within a one-mile corridor of the SAWS Recycled Water Program project area. Considering that the owner or controller of the project will likely be a political subdivision of the State of Texas (i.e. river authority, municipality, county, etc.), they will be required to coordinate with the Texas Historical Commission regarding if the project will affect waters of the United States or wetlands, the project sponsor will also be required to coordinate with the U.S. Army Corps of Engineers regarding impacts to cultural resources.

4C.3.4 Engineering and Costing

The planned expansion of the SAWS Recycled Water Program would more than double the distribution capacity of the existing system during the next fifty-five years. Other than the planned Southern Interconnections of the water recycling centers (wastewater treatment facilities) and the Northern Interconnection of the existing distribution systems, specific elements of an expanded system are unknown at this time. Hence, estimates of cost for expansion of system capacity by 36,258 acft/yr by 2060 are based upon actual and projected costs for

Table 4C.3-2
Important Species Having Habitat or Known to Occur in County Potentially Affected by San Antonio Water System (SAWS) Recycled Water Program; Phased Expansion (L-21)*

Common Name	*Scientific Name*	*Impact Value*	*Multiplier Based on Status*	*Adjusted Impact*	*Summary of Habitat Preference*	*Listing Entity*		*Potential Occurrence in County*
						USFS[1]	*TPWD[1]*	
American Peregrine Falcon	*Falco peregrinus anatum*	0	3	0	Open country; cliffs	DL	E	Nesting/ Migrant
Arctic Peregrine Falcon	*Falco peregrinus tundrius*	0	2	0	Open country; cliffs	DL	T	Nesting/ Migrant
Big Red Sage	*Salvia penstemonoides*	2	1	2	Moist Creek and stream bed edges; historic; introduced in native plant nursery trade			Resident
Black Bear	*Usus americanus*	0	2	0	Mountains, broken country, woods, brushlands, forests	T/SA; NL	T	Resident
Black-capped Vireo	*Vireo atricapillus*	0	3	0	oak-juniper woolands with distinctive patchy, two-layered aspect; shrub and tree layer with open, grassy spaces	LE	E	Nesting/ Migrant
Black Spotted Newt	*Notophthalmus meridionalis*	1	2	2	Found in wet or sometimes wet areas, such as arroyos, canals, ditches, or shallow depressions; Gulf Coastal Plain of the San Antonio River		T	Resident
Braken Bat Cave Meshweaver	Cicurina venii	0	3	0	Small eyeless spider, in Karst features in western Bexar County.	LE		Resident
Bracted twistflower	*Streptanthus bracteatus*	2	1	2	endemic, openings in juniper-oak woodlands, rocky slopes			Resident
Cagle's Map Turtle	*Graptemys caglei*	1	2	2	Guadalupe River System, transition areas between riffles and pools, nests within 30 ft of water's edges	C1	T	Resident
Cave Myotis Bat	Myotis velifer	2	1	2	colonial, and cave dwelling; hibernates in limestone caves of Edwards Plateau			Resident
Cokendolpher Cave Harvestman	*Texella cokendolpheri*	0	3	0	Small eyeless harvestman, karst features in north-central Bexar county.	LE		Resident
Comal Blind Salamander	*Eurycea tridentifera*	0	2	0	Endemic; semi-troglobitic; found in springs and waters of caves in Bexar and Comal Co		T	Resident

Table 4C.3-2 (Continued)

Correll's false dragon-head	*Physostegiacorrellii*	1	1	1	Wet soils including roadside ditches, irrigation channels			Resident
Edwards Plateau Spring Salamander	*Eurycea sp. 7*	1	1	1	Endemic; troglobitic; springs, seeps, cave streams, and creek headwaters			Resident
Elmendorf's Onion	*Allium elmendorfii*	1	1	1	Endemic; deep sands derived from Queen City and similar Eocene formations			Resident
Golden-cheeked Warbler	*Dendrpoica chrysoparia*	0	3	0	Juniper-oak woodlands; dependent on mature Ashe juniper (cedar) for nests	LE	E	Nesting/ Migrant
Government Canyon Bat Cave Spider	*Neoleptoneta microps*	0	3	0	Small, eyeless or essentially eyeless spider; karst features in N and NW Bexar Co.	LE		Resident
Government Canyon Bat Cave Spider	*Neoleptoneta microps*	0	3	0	Small, eyeless or essentially eyeless spider; karst features in N and NW Bexar Co.	LE		Resident
Government Canyon Bat Cave Meshweaver	Cicurina vespera	0	3	0	Small, eyeless spider, karst features in northwestern Bexar County.	LE		Resident
Ground Beetle #1	Rhadine exilis	0	3	0	Eyeless beetle, karst features in northern Bexar County.	LE		Resident
Ground Beetle #2	*Rhadine infernalis*	1	3	1	Small eyeless ground beetle; karst features in northern and western Bexar County.	LE		Resident
Guadalupe Bass	*Micropterus treculi*	1	1	1	Perennial streams of the Edward's plateau region			Resident
Helotes Mold Beetle	*Bastrisodes venyivi*	1	3	3	Small, essentially eyeless mold beetle; karst features in N and NW Bexar Co.	LE		Resident
Henslow's Sparrow	*Ammodramus henslowii*	1	1	1	Weedy fields or cut over areas; bare ground for running and walking			Nesting/ Migrant
Indigo Snake	*Drymarchon corais erebennus*	1	2	2	Grass prairies and sand hills; usually thornbush woodland and mesquie savannah of coastal plain		T	Resident
Keeled Earless Lizard	*Holbrookia propinqua*	1	1	1	Coastal dunes, Barrier islands and sandy areas			Resident
Madla's Cave Spider	*Cicurina madla*	1	3	3	Small, eyeless or essentially eyeless spider; karst features in N and NW Bexar Co.	LE		Resident
Manfreda Giant-skipper	**Stallingsia maculosus**	0	1	0	Small insect.			Resident
Mimic Cavesnail	*Phreatodrobia imitata*	0	1	0	Subaquatic found in two wells penetrating the Edwards Aquifer			

Table 4C.3-2 (Concluded)

Mountain Plover	**Charadrius montanus**	1	1	1	Non-breeding-shortgrass plains and fields, plowed fields and sandy deserts			Nesting/ Migrant
Parks' Jointweed	*Polygonella parksii*	1	1	1	South Texas Plains; subherbaceous annual in deep loose sands, spring-summer			Resident
Plains Spotted Skunk	*Spilogale putorius interrupta*	0	1	0	Prefers wooded, brushy areas and tallgrass prairie, fields, prairies, croplands, fence rows, farmyards, forest edges			Resident
Robber Baron Cave Spider	*Cicurina baronia*	1	3	3	Small, eyeless or essentially eyeless spider; karst features in N and NW Bexar Co.	LE		Resident
Sandhill woolywhite	*Hymenopappuscar rizoanus*	1	1	1	Endemic, deep loose sands of Carrizo, disturbed areas			Resident
Spot-tailed earless Lizard	*Holbrookia lacerata*	1	1	1	Central & Southern Texas; oak-juniper woodlands and mesquite-prickly pear			Resident
Texas Garter Snake	*Thamnophis sirtalis annectens*	1	1	1	Varied, especially wet areas; bottomlands and pastures			Resident
Texas Horned Lizard	*Phrynosoma cornutum*	1	2	2	Varied, sparsely vegetated uplands, grass, cactus, brush		T	Resident
Texas Salamander	Eurycea neotenes	1	2	2	Endemic, in caves, springs and seeps.		T	Resident
Texas Tortoise	*Gopherus berlandieri*	1	2	2	Open brush with grass understory; open grass and bare ground avoided; occupies shallow depressions at base of bush or cactus, underground burrows, under objects; active March-Nov		T	Resident
Toothless Blindcat	*Trogloglanis pattersoni*	0	2	0	Troglobitic, blind catfish endemic to the San Antonio pool of the Edward's Aquifer		T	Resident
White-faced Ibis	*Pelagis chihi*	0	2	0	Prefers freshwater marshes, sloughs, and irrigated rice fields		T	Migrant
Whooping Crane	*Grus americana*	0	3	0	Potential migrant	LE	E	Migrant
Widemouth Blindcat	*Satan eurystomus*	1	2	2	troglobitic, blind catfish endemic to the San Antonio pool of the Edward's Aquifer		T	Resident
Wood Stork	*Mycteria americana*	1	2	2	Forages in prairie ponds, ditches, and shallow standing water formerly nested in TX		T	Migrant
Zone-tailed Hawk	*Buteo albonotatus*	1	2	2	Arid, open country including deciduous or pine-oak woodland; nests in various habitats and sites		T	Nesting/ Migrant

[1]Texas Parks and Wildlife Department (TPWD), Unpublished 2005, March 2005, Data and Map Files of the Wildlife Science Research and Diversity Division maintained by TPWD, Austin, Texas.

* LE/LT=Federally Listed Endangered/Threatened E/SA, T/SA=Federally Listed Endangered/Threatened by Similarity of Appearance

C1=Federal Candidate for Listing DL, PDL=Federally Delisted/Proposed for Delisting NL=not Federally Listed E, T=State Listed Endangered/Threatened

PE, PT=Federally Proposed Endangered/ Threatened Blank = Rare, but no regulatory listing status

Table 4C.3-3.
Previously Recorded Sites within 1-Mile Corridor of the Proposed Southern and Northern Interconnections SAWS Recycled Water Program.

Sites	41BX120
	41BX124
	41BX125
	41BX226
	41BX1152
	41BX567
	41BX1572
	41BX1575

development of the existing 35,000 acft/yr system, which was $125,300,000 (1999 dollars)[5] plus estimated costs for the planned interconnections (remaining Southern (Leon Creek WRC to Dos Rios WRC) = $6,157,000 and Northern = $8,225,000 – both in 2004 dollars).[6] Assuming debt service at an annual percentage rate of 6 percent for 30 years, the annual unit cost for development of the existing system was about $260 per acft (1999 dollars). Applying this unit cost to the planned 36,258 acft/yr expansion of system capacity and adding estimated costs for the planned interconnections results in a Total Project Cost for expansion of the SAWS Recycled Water Program of about $154,764,000, adjusted to second quarter 2002 dollars. Amortizing this Total Project Cost and accounting for estimated operations and maintenance and pumping energy costs results in an estimated Total Annual Cost of $15,742,107 and an Annual Unit Cost of Water of $434 per acft or $1.33 per 1000 gallons).

The Cities of New Braunfels, San Marcos, and Seguin are selling treated municipal effluent to steam-electric power plants and mining operations at prices ranging from $108/acft to about $485/acft.

4C.3.5 Implementation Issues

Since SAWS has successfully implemented substantial phases of its Recycled Water Program, there do not appear to be major implementation issues to overcome in expansion of the program. Implementation of recommended Recycled Water Programs to meet projected water needs in Comal, Guadalupe, and Hays Counties will require the negotiation of supply agreements

[5] San Antonio Express-News, December 8, 1999.
[6] San Antonio Water System, Personal Communication, February, 1 2005.

between entities treating wastewater and water user groups seeking to purchase treated wastewater. Significant factors in such agreements may include points of delivery and financial responsibility for transmission systems to convey water from source to user. If transmission is to be accomplished via the bed and banks of a stream or river, certain authorizations may need to be obtained from the Texas Commission on Environmental Quality.

(This page intentionally left blank.)

4C.4 Projects Under Construction

There are four water supply, treatment, or transmission projects referenced in the 2001 South Central Texas Regional Water Plan that are presently under construction in the region. When completed, each of these projects will meet a part of the projected water needs of the region. The quantities of water of each project have been included as existing supply for the water user groups (WUGs) to be served. A description of each project is presented below, for information purposes.

4C.4.1 Western Canyon Regional Water Supply Project

The Guadalupe-Blanco River Authority (GBRA) is developing a water supply system that will withdraw water from Canyon Reservoir in Comal County, treat it, and distribute potable water to the following wholesale customers: City of Boerne, City of Fair Oaks Ranch, City of Bulverde, the Comal ISD, San Antonio Water System/San Antonio River Authority (SAWS/SARA) and other entities in rural Comal, Kendall, and Bexar Counties (Table 4C.4-1).

Table 4C.4-1
Western Canyon Water Supply Project Allocations in Needs Assessment for Water User Groups

Entity	*2010 Annual Total (acft/yr)*	*2060 Annual Total (acft/yr)*
City of Boerne	650	1,861
City of Fair Oaks	1,200	1,400
City of Bulverde	396	396
Comal Rural	200	1,471
Kendall Rural	732	1,500
Bexar Rural	0	50
SAWS/SARA	7,500	0
TOTAL	10,678	6,678

The project includes seven construction contracts, the first of which (Contract 4 for the water treatment plant) was awarded in the spring of 2004. The final two contracts were awarded in January 2005, and the project is scheduled for completion with the first delivery of water to GBRA's customers in late 2005.

The geographic layout of the service area and the project are shown in Figure 4C.4-1. The raw water intake is located on the south shore of Canyon Reservoir within Comal Park. This location was selected since it is one of the few accessible locations on the south side of the reservoir that also provides access to deep water. The design of the intake required a deep-water site to ensure water availability during drought conditions. The raw water pump station delivers water to the treatment plant located on Startz Hill approximately five miles away. The plant is a membrane-type plant that includes coagulation for total organic carbon removal, necessary for the reduction of disinfection byproducts. Water is delivered to customers from a pump station at the plant and two remote pump stations that deliver treated water through approximately 43 miles of pipelines. The total estimated cost of the project is approximately $82,000,000. This includes all elements of engineering, construction, land acquisition, and administrative and financing costs. The estimated cost of delivered treated water is between $2.75 and $2.85 per 1,000 gallons.

The GBRA's amended permit for Canyon Reservoir allows for diversion of an average of 90,000 acft/year, of which the GBRA's Board of Directors authorized a commitment of no more that 16,800 ac-ft/year (15 MGD) for the Western Canyon Regional Water Supply Project, with the remainder being reserved for other uses within the basin. Accordingly, the project is designed to initially deliver 10 MGD to GBRA's wholesale customers in the region, with provisions to expand the project to 15 MGD by the installation of additional pumps and treatment modules.

4C.4.2 Hays/IH-35 Water Supply Project (GBRA)

The Hays/IH-35 Water Supply Project is currently in bidding and construction phases and involves the delivery of stored water from Canyon Reservoir via diversion facilities at Lake Dunlap and a raw water pipeline from Lake Dunlap to a water treatment plant at San Marcos. From San Marcos, a treated water transmission pipeline paralleling IH 35 will supply water user groups in Hays County. The Hays/IH-35 Water Supply Project is the section from San Marcos to the City of Buda, and includes a 6 MGD pump station (expandable to 12 MGD) located at the San Marcos WTP and a potable water pipeline from the San Marcos WTP to Northern Hays County (Figure 4C.4-2).

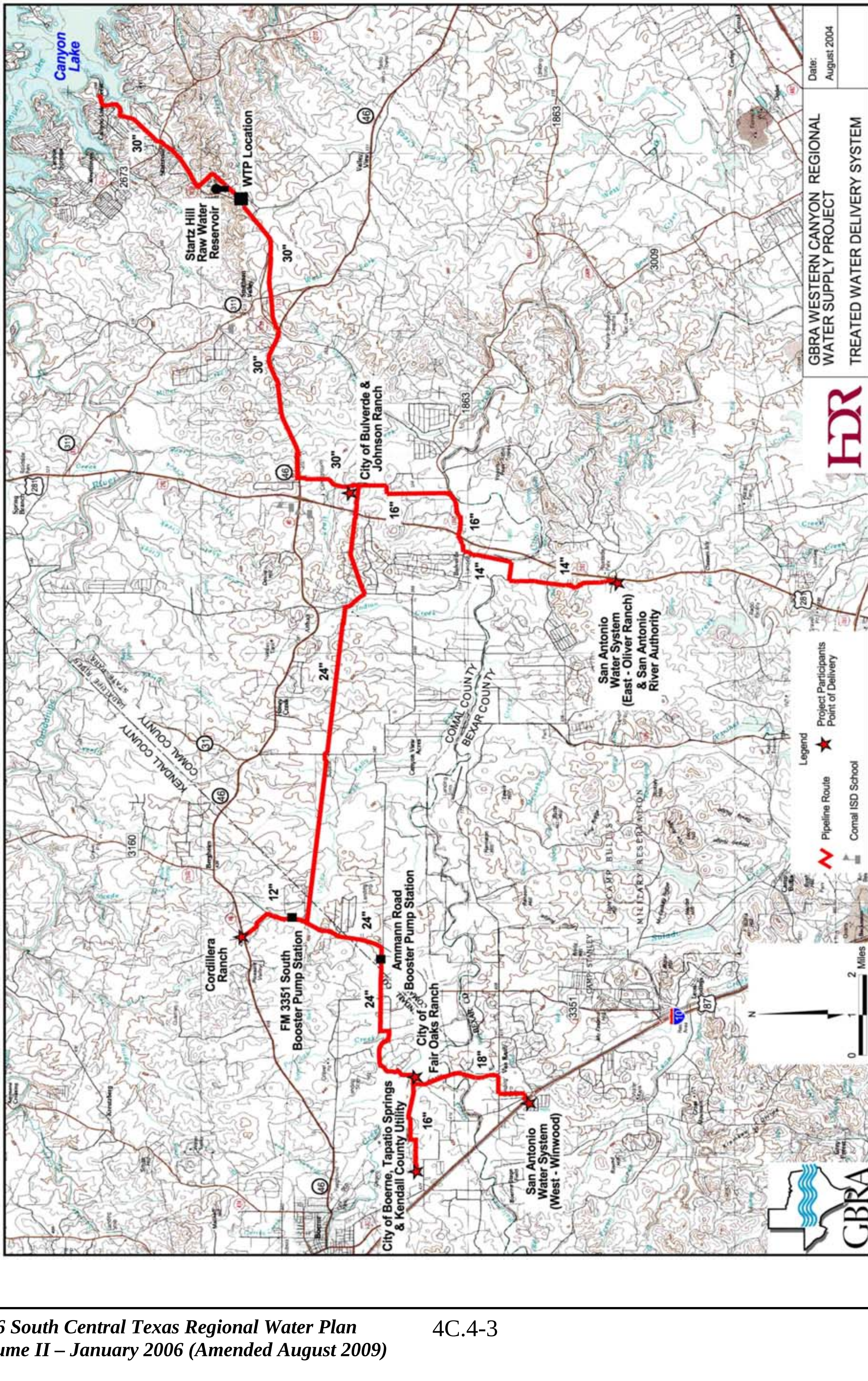


Figure 4C.4-1. GBRA Western Canyon Regional Water System

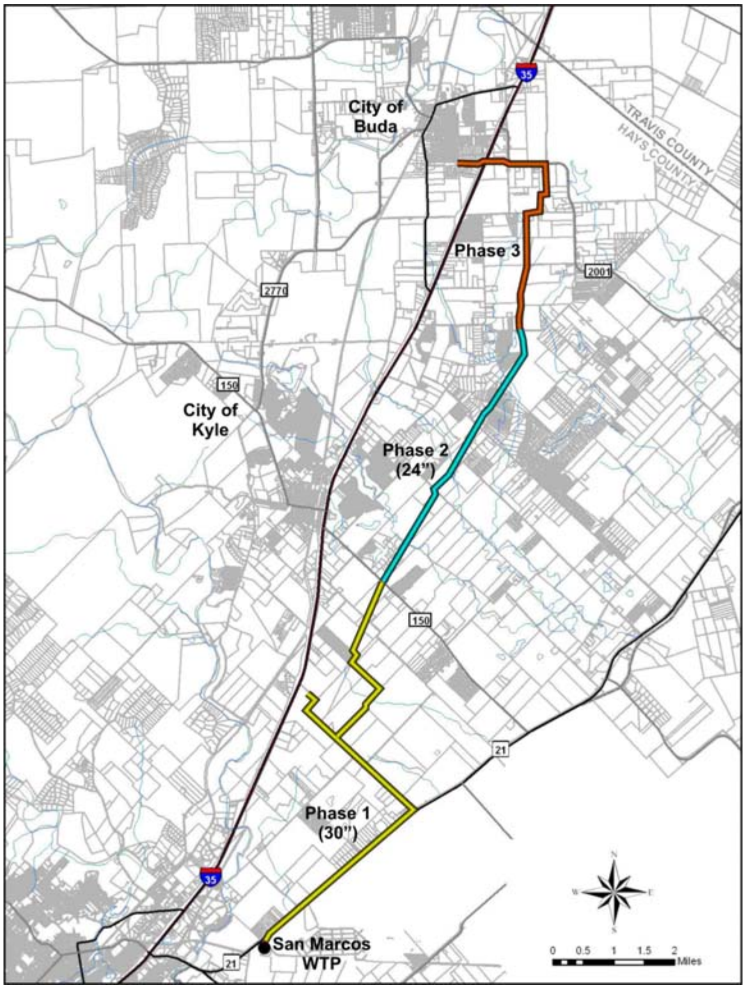


Figure 4C.4-2 Hays/IH-35 Water Supply Project

The current or planned contract amounts for the current GBRA customers of City of Kyle, City of Buda, and Goforth WSC for the years 2010 and 2060 are shown in Table 4C.4-2. Additional customers will also utilize the Hays/IH-35 Water Supply Project to meet future needs, but currently are not under contract.

Table 4C.4-2
Hays/IH-35 Water Supply Project Delivery Quantities

Customer	*YR 2010 Amount (acft/yr)*	*YR 2060 Amount (acft/yr)*
City of Kyle	2,957	4,111
City of Buda	1,120	1,120
Goforth WSC	1,000	3,000
TOTAL	5,077	8,231

The transmission pipeline is planned to be constructed in three phases. Phase one, which includes a 30-inch pipeline approximately 25,000 feet in length, is under construction, and is scheduled to be completed in late 2005. Phase two, construction of a 24-inch pipeline, also approximately 25,000 feet in length, has been bid and is scheduled for completion in late 2005. Phase three, which will be out for bid in mid-June 2005, will be approximately 8,500 feet in length.

The ultimate size of the project will be between 10 – 12 MGD (~11,000 – 13,500 acft/yr). The total estimated cost of the project is $17,000,000, although that does not include improvements to the San Marcos WTP and the raw water pipeline that would be necessary to reach the ultimate project size. The estimated unit cost of delivered treated water is about $3.00 per 1000 gallons.

4C.4.3 Lake Dunlap WTP Expansion and Mid-Cities Project (CRWA)

The Lake Dunlap Water Treatment Plant (WTP) Expansion and Mid-Cities Pipeline water management strategy is a project of the Canyon Regional Water Authority (CRWA) and in June 2005 was nearing the end of the construction phase. At completion, the Lake Dunlap WTP will supply up to 18 MGD of water to CRWA member entities including Springs Hill WSC, Green Valley SUD, East Central WSC, City of Marion, City of Cibolo, and Bexar Metropolitan Water District (BMWD) (NE Service Area). Figure 4C.4.-3 illustrates the transmission pipeline route. Water supply is diverted from Lake Dunlap, just northeast of New Braunfels, and delivered via a new 30-inch pipeline to the participating entities.

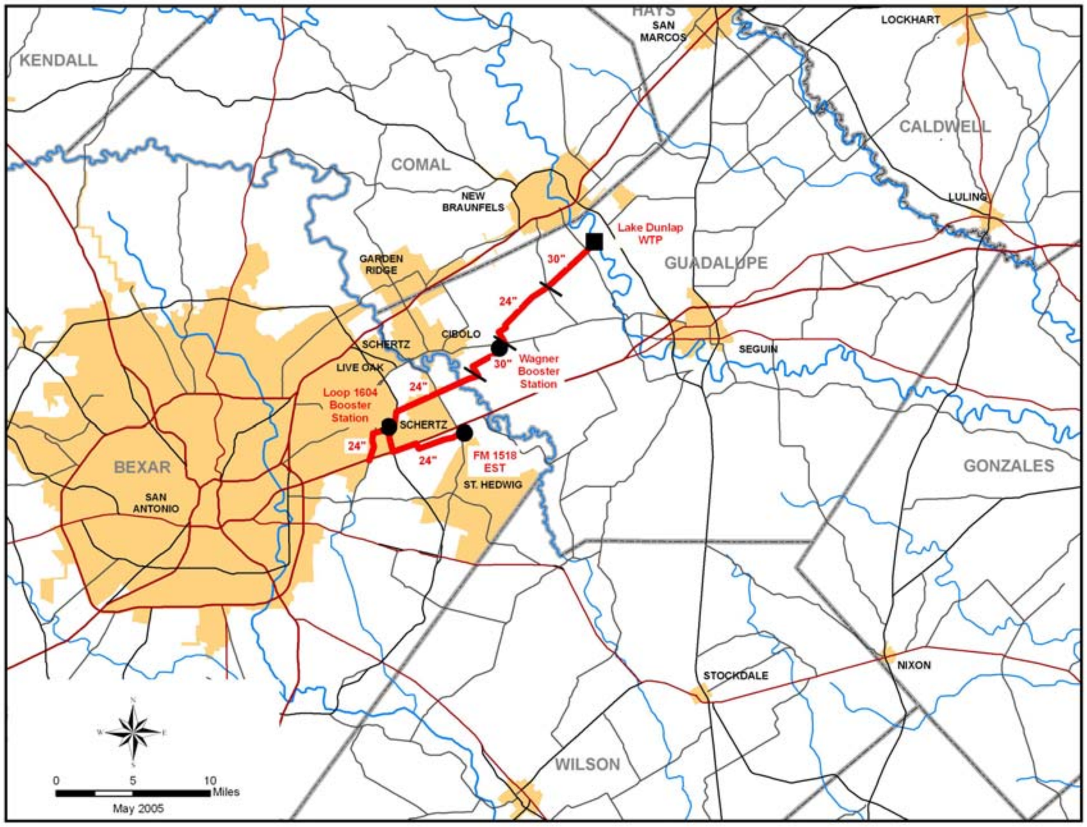


Figure 4C.4-3 Lake Dunlap WTP Expansion and Mid-Cities Project

4C.4.4 Aquifer Storage & Recovery (ASR) – Expansion of South Bexar County Facility

4C.4.4.1 Description of Water Management Strategy

Expansion of the San Antonio Water System (SAWS) Aquifer Storage and Recovery (ASR) System in south Bexar County is under construction at the time of this report (June 2005). Elements of this project include facilities for storage of water from the Edwards Aquifer during the winter, recovery of this water during the summer, and production of native groundwater. The South Bexar County ASR project consists of completed Phase I facilities and ongoing construction of Phase II facilities. When these phases are completed, the facilities will include:

- A pipeline between east-central San Antonio and the ASR facility;
- Facilities to divert 64 million gallons per day (MGD) of Edwards Aquifer water through this pipeline to the ASR well field;
- 60 MGD high-service pump station to pump recovered water back to east-central San Antonio;

- Water treatment plant (Twin Oaks) to remove excessive constituent concentrations from the native Carrizo water as needed;
- ASR well field with 29 wells; and
- Associated water collection pipeline and transmission pipelines between the ASR wells and Twin Oaks WTP.

The capacity of the well field is 64 MGD in injection mode and 60 MGD in recovery mode. The water management strategy involves potential expansion of this facility to store and recover up to 16 MGD of water that will be delivered by a water management strategy identified herein as Regional Carrizo for Bexar County.

Water is delivered from the Edwards Aquifer under two constraints. One is utilizing existing SAWS base permit plus purchased transfers of Edwards irrigation permits; and the other when the Edwards Aquifer is high. Also related to this project is a well field in the Carrizo Aquifer in Bexar County with a capacity of 10 MGD and an annual production limit of 6,400 acft/yr, pursuant to an agreement between SAWS and the Evergreen Underground Water Conservation District. The 6,400 acft/yr has been included as a part of the existing supply for SAWS. Costs for facilities and supplies associated with expansion of this well field are reported as part of the Regional Carrizo for Bexar County water management strategy (Section 4C.14). The location of project facilities is shown in Figure 4C.4-4. Dedicated production wells will be located on the upgradient side of the ASR well field to flatten the hydraulic gradient of the Carrizo to reduce the drift of the injected water, and to utilize some of the available groundwater supplies in the Carrizo Aquifer in south Bexar County. The proposed ASR project uses dual-purpose wells to inject available water into an aquifer for storage, with recovery of the water using the wells' pumping systems.

ASR facilities are useful to water suppliers who periodically have substantial quantities of water in excess of short-term needs and short-term demands in excess of current water supplies or system capacity. In this case, the ASR strategy allows a remote Carrizo Aquifer source to be delivered at a uniform, base rate for increased efficiency and cost effectiveness, while providing a means of meeting summer demands.

The South Bexar facilities may be operated in two ways. One will be on an annual cycle where the recharge and recovery are balanced each year. The second option allows for long-term storage during one or more extended wet periods and recovery during droughts.

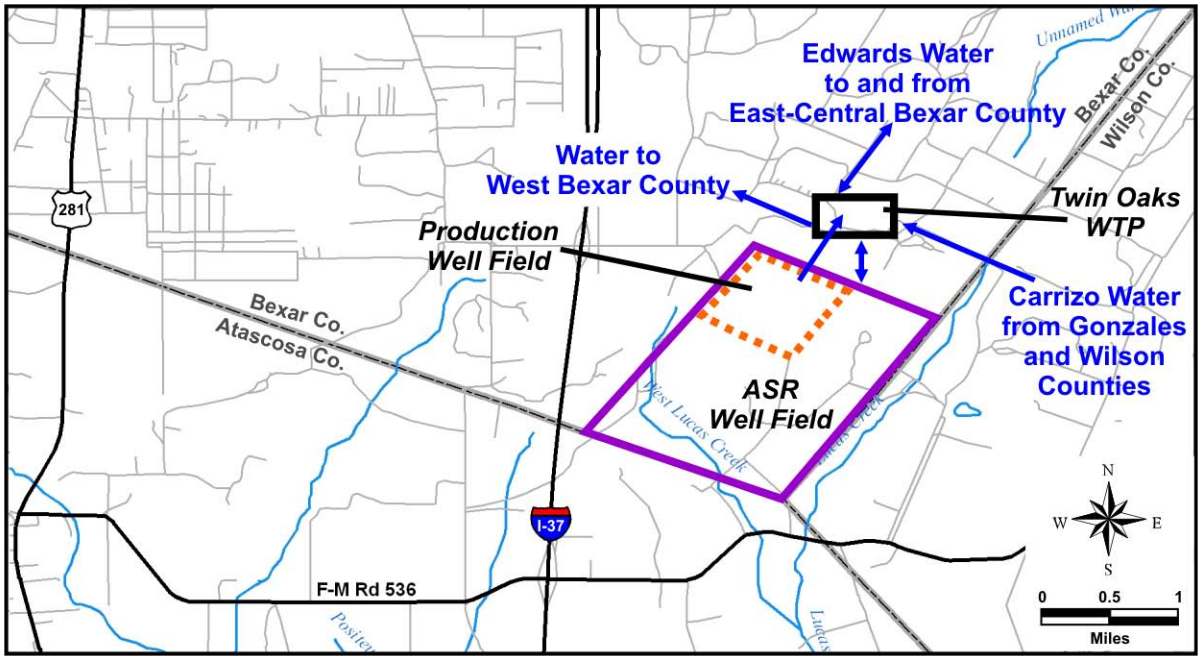


Figure 4C.4-4. Location of South Bexar Facilities

4C.4.4.2 Available Capacity

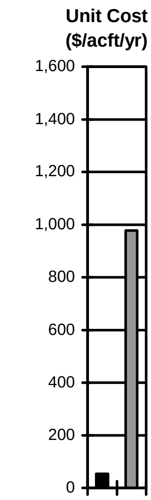
A previous evaluation and extensive field testing has determined that the Carrizo Aquifer in south Bexar County offers suitable characteristics for an ASR facility. Results of testing and evaluations indicate that ASR well fields should parallel the outcrop of the Carrizo Formation and be located about 5 to 7 miles southeast of the downdip limit of the outcrop. 1,2,3 Based upon this criteria, a south Bexar County ASR well field location was selected by SAWS. In the design of the well field, a MODFLOW groundwater model4 of the Carrizo-Wilcox Aquifer in this vicinity was developed and applied to assess aquifer response to ASR operations. Based on extensive local test data, the conceptual framework for the model divided the Carrizo Sands into three layers, (i.e., upper, massive, and lower). The model was calibrated to historical conditions and to several extended aquifer tests of pumping wells. Two of the model applications

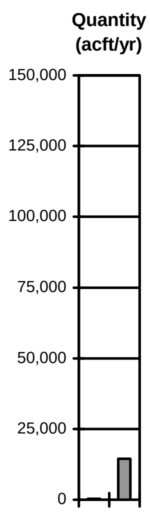
[1] Klemt, W.B., et al., "Ground-Water Resources of the Carrizo Aquifer in the Winter Garden Area of Texas," Texas Water Development Board (TWDB) Report 210, Vols. 1 and 2, 1976.
[2] HDR Engineering, Inc and LBG-Guyton Associates, "Interaction Between Ground Water and Surface Water in the Carrizo-Wilcox Aquifer," TWDB, 1998.
[3] Ryder, P.D. and Ardis, A.F., "Hydrology of the Texas Gulf Coast Aquifer System." U.S. Geological Survey Open-File Report 91-64, 1991.
[4] HDR Engineering, Inc, "Numerical Groundwater Model of South Bexar County ASR Well Field," Prepared for San Antonio Water System, December 2003.

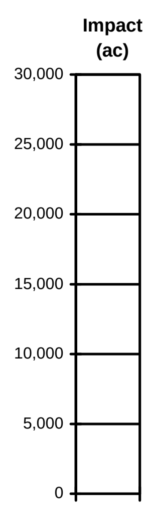
considered: (1) balancing the recharge and recovery within an annual cycle; and (2) a 40-year simulation where up to 250,000 acft of water was banked over a 24-year period, and recovered during a following 7-year drought. These applications were performed for seasonal injection and recovery rates up to 80 MGD. Because the Carrizo Aquifer in this area is very transmissive and near the recharge zone, the modeling results show that the aquifer has great capacity to support significant pumping and recharge events. Long-term simulations indicate that problematic mounding of water levels to the point were water levels would be above the land surface is not expected. Drift of the injected water beyond the recovery zone of the wells has not been quantified, but is expected to occur for wells on the perimeter. Considering that the native Carrizo water is potable, except for elevated concentrations of iron and manganese, the recovered water may not be 100 percent injected water, but the modeling studies indicate that the aquifer is able to support recovery of the banked water, even at a much later date.

(This page intentionally left blank.)

2006 South Central Texas Regional Water Plan
Water Management Strategy Summary Sheet







Name: Canyon Reservoir

Description: Strategy involves the purchase of Canyon Reservoir stored water from the Guadalupe-Blanco River Authority (GBRA), transmission and treatment facilities, and integration of additional supply. Planned implementation of this strategy includes diversions directly from Canyon Reservoir and diversions from the Guadalupe River at various locations downstream of Canyon Dam. Presently uncontracted supplies of firm stored water from Canyon Reservoir are between 20,000 acft/yr and 25,000 acft/yr. This water management strategy is more generally identified as "Purchase from Wholesale Water Provider (GBRA)" and is recommended for entities with projected water needs in Caldwell, Comal, Guadalupe, Hays, Kendall, and Victoria Counties. Unit costs for this water supply are dependent upon location and appurtenant transmission and treatment facilities unique for each customer.

***Decade Needed*:** 2000 – 2020

Cost, Quantity of Water, and Land Impacted

Unit Cost of Water:	**$54 - $977**	**$/acft/yr**	**Treated Water Delivered**
Quantity of Water:	**354 - 15,000**	**acft/yr**	**Reliability = Firm**
Land Impacted:	**N/A**	**acres**	

Additional Considerations per Regional Water Planning Guidelines

Environmental Factors:

Downstream deliveries of stored water enhance instream flows and lower water temperatures during drought periods.

Impacts on Water Resources:

None anticipated. Source of water is authorized diversions from existing reservoir.

Impacts on Agricultural & Natural Resources:

Minimal, if any.

Other Relevant Factors per SCTRWPG:

Encourages beneficial use of available rights. Protects instream flows and recreational opportunities between Canyon Reservoir and downstream delivery points.

Comparison of Strategies to Meet Needs:

Low to Moderate unit cost. No conflicts with other recommended water management strategies.

Interbasin Transfer Issues:

None.

Third-Party Impacts of Voluntary Transfers:

None anticipated.

Regional Efficiency:

Water source proximate to customers through direct diversion or river delivery. Western Canyon Water Supply Project and Hays/IH35 Water Supply Project each serve multiple water user groups with needs.

Water Quality Considerations:

None anticipated.

(This page intentionally left blank.)

4C.5 Canyon Reservoir

4C.5.1 Description of Water Management Strategy

The Canyon Reservoir water management strategy involves the purchase of Canyon Reservoir stored water from the Guadalupe-Blanco River Authority (GBRA), transmission and treatment facilities, and integration of additional supply. Canyon Reservoir is located on the Guadalupe River in Comal County and is about 14 miles west of San Marcos and 12 miles northwest of New Braunfels. The U.S. Army Corps of Engineers (USCE) initiated construction of the water supply and flood control project in 1958, with deliberate impoundment of water beginning in 1964. The reservoir has 386,200 acft of authorized conservation storage; impounds runoff from 1,432 square miles of drainage area; and inundates 8,231 acres at the full conservation storage level of 909 ft-msl. The conservation storage pool of Canyon Reservoir is owned and operated by the GBRA. Planned implementation of this strategy includes diversions directly from Canyon Reservoir and diversions from the Guadalupe River at various locations downstream of Canyon Dam. Presently uncontracted supplies of firm stored water from Canyon Reservoir are between 20,000 acft/yr and 25,000 acft/yr. This water management strategy is more generally identified as “Purchase from Wholesale Water Provider (GBRA)” and is recommended for entities with projected water needs in Caldwell, Comal, Guadalupe, Hays, Kendall, and Victoria Counties.

The Western Canyon Water Supply Project and Hays/IH35 Water Supply Project (presently under construction) facilitate greater use of available supplies from Canyon Reservoir to meet needs in the GBRA district. Water User Groups (WUGs) expected to receive water from these two strategies to meet projected needs include:

- Western Canyon Water Supply Project (WCWSP)[1]
  - City of Bulverde
  - Comal County Other
  - Kendall County Other

[1] Additional WUGs or Wholesale Water Providers (WWPs) expected to receive water through the WCWSP include, but are not limited to, the Cities of Boerne and Fair Oaks Ranch, San Antonio Water System, and San Antonio River Authority.

- Hays/IH35 Water Supply Project (Hays/IH35 WSP)[2]
  - Goforth WSC
  - City of Kyle
  - City of Niederwald
  - Hays County Other

Cost estimates for treated water supplies delivered to these seven WUGs are provided in Section 4C.5.3. Volume II, Section 4C.4 contains more information regarding the WCWSP and Hays/IH35 WSP.

Canyon Lake WSC purchases and diverts water directly from Canyon Reservoir, then treats and distributes that water to customers around Canyon Reservoir in Comal County. Year 2060 needs for Canyon Lake WSC total 9,331 acft/yr. A cost estimate for additional supplies for Canyon Lake WSC is provided in Section 4C.5.4.

New Braunfels Utilities (NBU) currently diverts water from the Guadalupe River downstream of Canyon Reservoir. This strategy includes the purchase of Canyon Reservoir water to meet the growing needs of the City of New Braunfels. Year 2060 needs for NBU, all of which are expected to be met by Canyon Reservoir, are about 15,000 acft/yr. A cost estimate for additional NBU supplies is provided in Section 4C.5.4.

Goliad County Steam Electric (Coleto Creek Power) and Victoria County Industrial, have projected needs of about 4,500 acft/yr and 6,600 acft/yr, respectively, in 2060. Most of these needs will be met from GBRA's existing lower basin water rights. In order to ensure that a firm supply is available to meet these projected needs, it is assumed that a commitment of stored water from Canyon Reservoir equal to approximately one-third of the projected needs may be necessary. Cost estimates for additional supplies for these two WUGs are provided in Section 4C.5.4.

4C.5.2 Available Yield

In 2001, GBRA was granted an amendment to Certificate of Adjudication No. 18-2074 increasing the authorized diversions from Canyon Reservoir for municipal, industrial, and other purposes from an average of 50,000 acft/yr to an average of 90,000 acft/yr. The firm yield of Canyon Reservoir is dependent upon a number of factors including points of diversion for

---

[2] Additional WUGs or Wholesale Water Providers (WWPs) expected to receive water through the Hays/IH35 WSP include, but are not limited to, the Cities of Buda and Mustang Ridge, Plum Creek WC, and County Line WSC.

contracted supplies, Edwards Aquifer springflow, term recreational flow agreements, and discharge of treated effluent throughout the Guadalupe – San Antonio River Basin. Subject to hydrologic assumptions and operational procedures listed in Section 3.2.3.1, estimates of Canyon Reservoir firm yield (calculated using the GSA WAM) range from 88,232 acft/yr to 87,484 acft/yr in years 2000 and 2060, respectively.

4C.5.3 Environmental Issues

The Canyon Reservoir water management strategy involves diversion and use of water that is currently authorized for use under Certificate of Adjudication No. 18-2074E, hence environmental issues have been sufficiently addressed through the inclusion of special conditions in the certificate. This management strategy would increase flows in the Guadalupe River between Canyon Dam and New Braunfels during drought. Water levels in Canyon Reservoir may be expected to fluctuate to a greater degree as more of the firm yield is delivered to customers. Even with full delivery of the firm yield, however, simulations indicate that Canyon Reservoir is expected to be full (at or above 909 ft-msl) more than 40 percent of the time.

4C.5.4 Engineering and Costing

Unit costs for this water supply are dependent upon location and appurtenant transmission and treatment facilities unique for each customer. With the exceptions of Canyon Lake WSC and delivery via the WCWSP, water would be released at Canyon Dam and allowed to flow downstream to various WUGs and/or projects serving WUGs along the Guadalupe River.

The water committed to WUGs utilizing the Hays/IH35 WSP would be delivered to Lake Dunlap where it would be diverted and transmitted to the San Marcos WTP via GBRA's San Marcos pipeline, treated, and then delivered via the Hays/IH35 WSP. GBRA's water purchase cost for the Hays/IH35 WSP is $3.00/kgal, or about $977/acft (Table 4C.5-1).

Water committed to customers of the WCWSP would be diverted directly from the reservoir and delivered via the WCWSP transmission system. GBRA's water purchase cost for the WCWSP is approximately $2.80/kgal, or $912/acft (Table 4C.5-1).

Canyon Lake WSC's commitment will also be diverted directly from the reservoir. A rough cost estimate to determine the associated cost of expanding diversions, treatment, and integration provided a unit cost of approximately $438/acft, including debt service, O&M, and power costs (Table 4C.5-1).

Water committed to NBU would be delivered via the Guadalupe River to an intake on the Guadalupe River in New Braunfels, where diversions in the amount of 15,000 acft/yr would be made in a seasonal pattern. The major facilities required to implement this portion of the strategy are:

- Intake and Pump Station Expansion
- Raw Water Pipeline to Treatment Plant
- Water Treatment Plant Expansion

The intake and pump station is sized to deliver ~1,500 acft/month (16 MGD) through a 33-inch diameter pipeline. The operating cost was determined for the delivery of 15,000 acft/year through expansion of the existing water treatment plant. Financing the project over 30 years at 6.0 percent annual interest rate results in annual debt service of $1,694,000 (Table 4C.5-2). The annual cost to purchase water from GBRA is $84 per acft, resulting in a payment of $1,260,000 per year for water. Operation and maintenance costs, including power and purchase of stored water, total $2,715,000 per year. The total annual costs, including debt repayment, interest, and operation and maintenance, total $4,409,000. For an annual firm supply of 15,000 acft, the resulting annual cost of water is $294 per acft (Table 4C.5-2).

Estimated costs to provide firm water supply to meet projected needs for Coleto Creek Power and Victoria County industry are based on the GBRA Lower Basin rate of $0.08/kgal for 100 percent of the annual need plus firm-up supply from Canyon Reservoir at a rate of $84/acft for one-third of the annual need. The resulting unit cost of water for these two WUGs is $54/acft (Table 4C.5-1).

Table 4C.5-1
Cost Estimate Summary for
WUGs Utilizing Canyon Reservoir Water
Second Quarter 2002 Prices

WUG	Item	Data	Cost Estimate Notes
Bulverde	***Need @ 2060 (acft/yr)***	4,595	Based on Western Canyon Water Supply Project rate of $2.80/kgal.
	Annual Cost ($)	$4,191,815	
	Unit Cost ($/acft)	$912	
Canyon Lake WSC	***Need @ 2060 (acft/yr)***	9,331	Based on purchase of raw water from GBRA as well as construction and operation of intake, transmission, and treatment facilities. The larger numbers include debt service and O&M and the smaller numbers are O&M only.
	Annual Cost ($)	$4,086,978 $1,968,841	
	Unit Cost ($/acft)	$438 $211	
New Braunfels	***Need @ 2060 (acft/yr)***	14,475	Based on purchase of raw water from GBRA as well as construction and operation of intake, transmission, and treatment facilities. The larger numbers include debt service and O&M and the smaller numbers are O&M only.
	Annual Cost ($)	$4,255,650 $2,619,975	
	Unit Cost ($/acft)	$294 $181	
Comal County Other	***Need @ 2060 (acft/yr)***	2,071	Based on Western Canyon Water Supply Project rate of $2.80/kgal.
	Annual Cost ($)	$1,889,281	
	Unit Cost ($/acft)	$912	
Goliad County Steam Electric	***Need @ 2060 (acft/yr)***	4,482	Based on GBRA Lower Basin rate of $0.08/kgal for 100% of the annual need plus firm-up supply from Canyon Reservoir at a rate of $84/acft for one-third of the annual need. No additional facility costs included.
	Annual Cost ($)	$242,028	
	Unit Cost ($/acft)	$54	
Goforth WSC	***Need @ 2060 (acft/yr)***	3,000	Based on Hays/IH35 Water Supply Project rate of $3.00/kgal.
	Annual Cost ($)	$2,932,250	
	Unit Cost ($/acft)	$977	
Kyle	***Need @ 2060 (acft/yr)***	3,522	Based on Hays/IH35 Water Supply Project rate of $3.00/kgal.
	Annual Cost ($)	$3,442,462	
	Unit Cost ($/acft)	$977	
Niederwald	***Need @ 2060 (acft/yr)***	354	Based on Hays/IH35 Water Supply Project rate of $3.00/kgal.
	Annual Cost ($)	$346,006	
	Unit Cost ($/acft)	$977	
Hays County Other	***Need @ 2060 (acft/yr)***	4,480	Based on Hays/IH35 Water Supply Project rate of $3.00/kgal.
	Annual Cost ($)	$4,378,827	
	Unit Cost ($/acft)	$977	

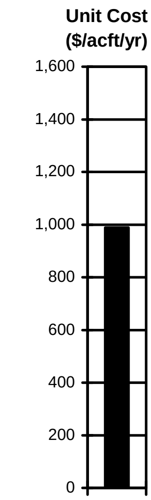
Table 4C.5-1 Continued

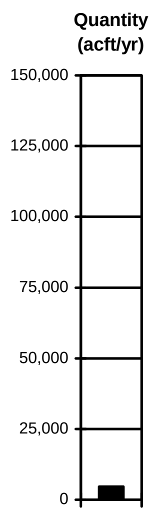
Kendall County Other	***Need @ 2060 (acft/yr)***	4,163	Based on Western Canyon Water Supply Project rate of $2.80/kgal.
	Annual Cost ($)	$3,797,720	
	Unit Cost ($/acft)	$912	
Victoria County Industrial	***Need @ 2060 (acft/yr)***	6,566	Based on GBRA Lower Basin rate of $0.08/kgal for 100% of the annual need plus firm-up supply from Canyon Reservoir at a rate of $84/acft for one-third of the annual need. No additional facility costs included.
	Annual Cost ($)	$354,564	
	Unit Cost ($/acft)	$54	

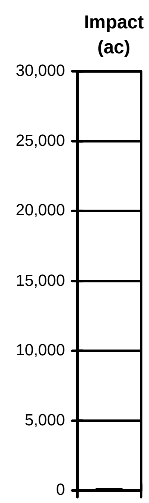
Table 4C.5-2
Cost Estimate Summary for
Canyon Reservoir Water Released to New Braunfels Utilities
Second Quarter 2002 Prices

Item	***Estimated Costs for Facilities***
Capital Costs	
Intake and Pump Station (16 MGD)	$1,241,000
Transmission Pipeline (33 in dia., 0 miles)	$301,000
Water Treatment Plant Expansion (from 8 MGD to 24 MGD)	$13,324,000
Total Capital Cost	**$14,866,000**
Engineering, Legal Costs and Contingencies	$5,188,000
Environmental & Archaeology Studies and Mitigation	$23,000
Land Acquisition and Surveying (10 acres)	$28,000
Interest During Construction (4 years)	$3,217,000
Total Project Cost	**$23,322,000**
Annual Costs	
Debt Service (6 percent, 30 years)	$1,694,000
Operation and Maintenance	
Intake, Pipeline, Pump Station	$34,000
Water Treatment Plant	$1,309,000
Pumping Energy Costs (1,863,806 kW-hr @ 0.06 $/kW-hr)	$112,000
Purchase of Water (15,000 acft/yr @ 84 $/acft)	$1,260,000
Total Annual Cost	**$4,409,000**
Available Project Yield (acft/yr)	15,000
Annual Cost of Water ($ per acft)	$294
Annual Cost of Water ($ per 1,000 gallons)	$0.90

2006 South Central Texas Regional Water Plan
Water Management Strategy Summary Sheet







Name: **Wimberley and Woodcreek Water Supply from Canyon Reservoir Purchase from Wholesale Water Provider**

Description: Facilities include an intake, pump station, and water treatment plant near Canyon Reservoir and a 24-inch treated water transmission pipeline delivering water a distance of approximately 18 miles to Wimberley WSC, Woodcreek, and Woodcreek Utilities. Strategy has capacity to meet projected 2060 peak day water needs with water from Canyon Reservoir obtained by contract with the Guadalupe-Blanco River Authority.

***Decade Needed*:** 2000 – 2010

Cost, Quantity of Water, and Land Impacted

Unit Cost of Water:	**989**	**$/acft/yr**	**Treated Water Delivered**
Quantity of Water:	**4,636**	**acft/yr**	**Reliability = Firm**
Land Impacted:	**74**	**acres**	

Additional Considerations per Regional Water Planning Guidelines

Environmental Factors:

Pipeline could traverse Black-capped Vireo and/or Golden-cheeked Warbler habitat.

Impacts on Water Resources:

Minimal, as source of supply is authorized diversion and use from Canyon Reservoir.

Impacts on Agricultural & Natural Resources:

Not applicable.

Other Relevant Factors per SCTRWPG:

Encourages beneficial use of existing reservoir.

Comparison of Strategies to Meet Needs:

Options to meet needs are limited. No conflicts with other recommended water management strategies.

Interbasin Transfer Issues:

Not applicable.

Third-Party Impacts of Voluntary Transfers:

Not applicable.

Regional Efficiency:

Additional surface water supply without construction of a new reservoir.

Water Quality Considerations:

None of significant concern.

(This page intentionally left blank.)

4C.6 Wimberley and Woodcreek Water Supply from Canyon Reservoir

4C.6.1 Description of Water Management Strategy

The communities of Wimberley and Woodcreek are located next to each other near the Blanco River, within the Guadalupe River Basin, in Hays County, about 12 miles to the northeast of Canyon Reservoir (Figure 4C.6-1). As is the case of many subdivisions around Canyon Reservoir, water has been obtained from wells in the Trinity Aquifer and supplied by water supply corporations or other retail entities. Municipal water supplies for Wimberley and Woodcreek are provided by Wimberley Water Supply Corporation (WSC) and Woodcreek Utilities, Inc. As supplies from the Trinity Aquifer are expected to be inadequate to meet all of the projected demands for these entities, one potential source of additional water supply is Canyon Reservoir. This supply could be accessed by purchasing water from a wholesale water provider or, more specifically, entering into a water supply contract with the Guadalupe-Blanco River Authority (GBRA) and constructing a pipeline that would bring water from a water treatment plant at Canyon Reservoir to the entities for retail distribution.

In 2000, total water use in the Wimberley and Woodcreek communities was 1,166 acft, all of which was obtained from the Trinity Aquifer. Comparison of projected water demands and existing supplies from the Trinity Aquifer indicates projected needs for additional water supplies ranging from 770 acft/yr in 2010 to 4,636 acft/yr in 2060. Hence, this water management strategy has been sized and a cost estimate prepared to provide 4,636 acft/yr of reliable, additional water supply.

4C.6.2 Available Yield

The firm yield of Canyon Reservoir is defined to be the maximum amount of water the reservoir can supply through a repeat of the drought of record.

The year 2030 and 2060 projected water needs for the Wimberley/Woodcreek area are 2,177 and 4,636 acft/yr, respectively. With the recent amendment of Certificate of Adjudication No. 18-2074 (CA #18-2074E), the uncommitted firm yield of Canyon Reservoir has been increased substantially. Therefore, the projected water needs for the area can be met with Canyon Reservoir yield, provided a purchase contract is signed with GBRA. For conceptual design, costing, and environmental analyses, the treatment and transmission systems are sized to meet the projected year 2060 needs of 4,636 acft/yr.

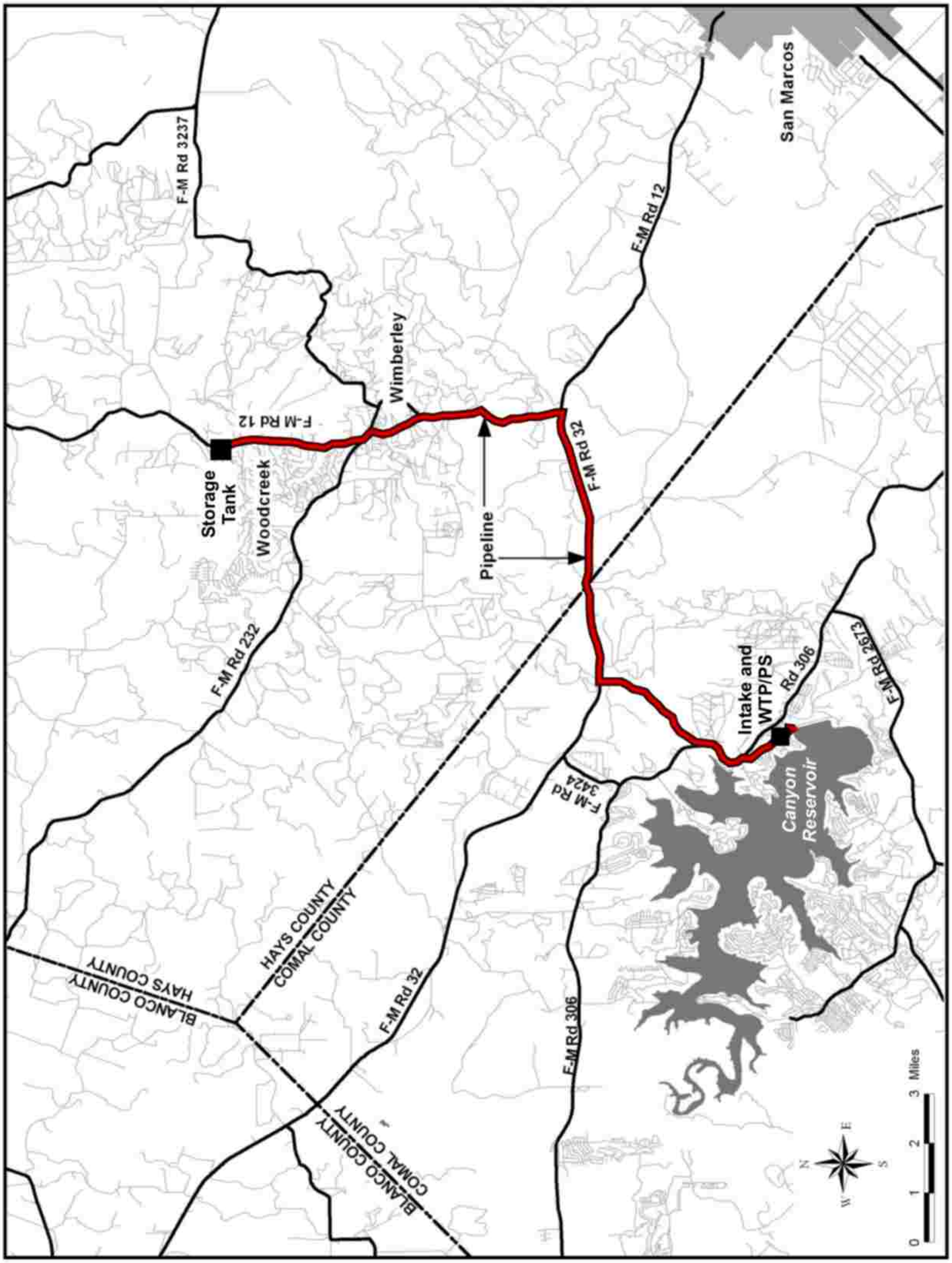


Figure 4C.6-1. Wimberley and Woodcreek Water Supply from Canyon Reservoir

4C.6.3 Environmental Issues

Wimberley and Woodcreek communities are located about 12 miles northeast of Canyon Reservoir in Hays County on a tributary of the Blanco River at about 800 to 900 ft-msl (Figure 4.2-1). Spring-fed Cypress Creek flows through the center of the town of Wimberley. Large cypress trees line Cypress Creek and a portion of the nearby Blanco River. The scenic Wimberley area on the eastern Edwards Plateau is a popular tourist destination, and both the Blanco River and Cypress Creek are heavily used recreational resources. Both have been nominated by Texas Parks and Wildlife Department as Ecologically Significant River and Stream Segments.

Land use in Wimberley and Woodcreek is rural residential, suburban residential and recreational. Most of the surrounding land use is rangeland. Although an alignment study has not been performed, this report assumes that the waterline right-of-ways will cross the Blanco River west of the FM 12 crossing avoiding the stands of mature cypress on the stream banks and the springs at Wimberley.

Vegetation on the pipeline corridor consists primarily of live oak-ashe juniper savanna (46 percent) and mesquite invaded plateau live oak with midgrass series rangeland (48 percent). Developed areas total 5 percent and wetlands occupy less than 1 percent of the study corridor. There are relatively few streams and ponds that supply water for livestock in this area. Most unnamed creeks are typically intermittent and similar to small creeks found around Canyon Reservoir. Important water resources in the study corridor are the Blanco River, Cypress Creek and a multitude of associated Edwards Aquifer springs.[1,2,3,4]

Important species known to occur in Hays and Comal Counties are listed in Table 4C.6-1. Although the species listed in this table do not necessarily occur at the specific locations that would be disturbed during development of water supply facilities, this list of species and their preferred habitats that would need to be investigated, or considered during a route selection

---

[1] USFWS, National Wetland Inventory Map Series, Devils Backbone and Wimberley, Texas Quadrangles, USGS, 1991.
[2] Texas Parks and Wildlife Department (TPWD), Unpublished 2005, March 2005, Data and Map Files of the Wildlife Science Research and Diversity Division maintained by TPWD, Austin, Texas.
[3] Gould, F.W., "Texas Plants; A Checklist And Ecological Summary," Texas A&M University, Texas Agricultural Experiment Station, MP-585/Rev., College Station, Texas, 1975.
[4] McMahan, C.A., R.G. Frye, K.L. Brown, "The Vegetation Types of Texas Including Cropland," TPWD, Austin, Texas, 1982.

Table 4C.6-1.
Important Species* Having Habitat or Known to Occur in Counties Potentially Affected by Wimberley and Woodcreek Water Supply from Canyon Reservoir

Common Name	Scientific Name	Impact Value	Multiplier Based on Status	Adjusted Impact	Summary of Habitat Preference	Listing Entity USFWS[1]	Listing Entity TPWD[1]	Potential Occurrence in County
American Peregrine Falcon	*Falco peregrinus anatum*	0	3	0	Open country; cliffs	DL	E	Nesting/Migrant
Arctic Peregrine Falcon	*Falco peregrinus tundrius*	0	2	0	Open country; cliffs	DL	T	Nesting/Migrant
Balcones Cave Amphipod	*Stygobromus balconies*	1	1	1	Small subterranean amphipod found in cave pools.			Resident
Black Bear	*Ursus americanus*	0	2	0	Inhabits bottomland hardwoods.	T/SA;NL	T	
Black-capped Vireo	*Vireo atricapillus*	1	3	3	Semi-open broad-leaved shrublands	LE	E	Nesting/Migrant
Blanco Blind Salamander	*Eurycea robusta*	2	2	4	Troglobitic; Stream bed of the Blanco River		T	Resident
Blanco River Springs Salamander	*Eurycea pterophila*	2	1	2	Subaquatic; Springs and caves of the Blanco River			Resident
Blue Sucker	*Cycleptus elongatus*	1	2	2	Channels and flowing pools with exposed bedrock		T	Resident
Bracted Twistflower	*Streptanthus bracteatus*	1	1	1	Endemic; Shallow clay soils over limestone; rocky slopes			Resident
Cagle's Map Turtle	*Graptemys caglei*	1	2	2	Waters of the Guadalupe River Basin	C1	T	Resident
Canyon Mock-Orange	*Philadelphus ernestii*	1	1	1	Edwards Plateau			Resident
Cascade Caverns Salamander	*Eurycea latitans*	1	2	2	Endemic; Subaquatic; Springs and caves		T	Resident
Cave Myotis Bat	*Myotis velifer*	0	1	0	Colonial & cave dwelling; hibernates in limestone caves of Edwards Plateau			Resident
Comal Blind Salamander	*Eurycea tridentifera*	1	2	2	Endemic; Semi-troglobitic; Springs and waters of caves		T	Resident

Table 4C.6-1 continued

Comal Springs Diving Beetle	*Comaldessus stygius*	0	1	0	Known only from the outflows at Comal Springs; aquatic.			Resident
Comal Springs Dryopid Beetle	*Stygopamus comalensis*	1	3	3	Cling to objects in streams; adults fly especially at night	LE		Resident
Comal Springs Riffle Beetle	*Heterelmis comalensis*	1	3	3	Comal and San Marcos Springs	LE		Resident
Comal Springs Salamander	*Eurycea sp. 8*	0	1	0	Endemic; Comal Springs			Resident
Edwards Aquifer Diving Beetle	*Haideoporus texanus*	0	1	0	Habitat poorly known; known from artesian well			Resident
Edwards Plateau Spring Salamander	*Eurycea sp. 7*	2	1	2	Endemic; troglobitic; springs, seeps, cave streams, and creek headwaters; often hides under rocks and leaves in the water.			Resident
Ezell's Cave Amphipod	*Stygobromus flagelloatus*	0	1	0	Known from artesian wells			Resident
Flint's Net-Spinning Caddisfly	*Cheumatopsyche flinti*	1	1	1	Poorly known species with habitat listed as spring.			Resident
Fountain Darter	*Etheostoma fonticola*	0	3	0	San Marcos and Comal rivers; springs and spring-fed streams	LE	E	Resident
Glass Mountain Coral root	*Hexalectric nitida*	2	1	2	Plant			Resident
Golden-Cheeked Warbler	*Dendroica chrysoparia*	2	3	6	Woodlands with oaks and old juniper	LE	E	Nesting/Migrant
Guadalupe Bass	*Micropterus treculi*	2	1	2	Streams of eastern Edwards Plateau			Resident
Guadalupe Darter	*Percina sciera apristis*	0	1	0	Typically found over gravel or gravel and sand raceways of medium streams, rivers and pools.			Resudent
Henslow's Sparrow	*Ammodramus henslowii*	1	1	1	Weedy fields or cut over areas; bare ground for running and walking			Nesting/Migrant
Hill Country Wild-Mercury	*Argythamnia aphoroides*	1	1	1	Shallow to moderately deep clays; live oak woodlands			Resident

Table 4C.6-1 continued

Horseshoe Liptooth	*Polygyra hippocrepis*	0	1	0	Steep, wooded hillsides of Land Park in New Braunfels			Resident
Keeled Earless Lizard	*Holbrookia propinqua*	0	1	0	Coastal dunes, Barrier islands and sandy areas			Resident
Long-legged Cave Amphipod	*Stygobromus longipes*	1	1	1	Subaquatic crustacean; subterranean obligate; found in subterranean streams.			Resident
Mountain Plover	*Charadrius montanus*	1	1	1	Breeding, nests on ground in shallow depression.			Migrant
Peck's Cave Amphipod	*Stygobromus pecki*	0	3	0	Underground in Edwards aquifer	LE	E	Resident
Plains Spotted Skunk	*Spilogale putorius interrupta*	1	1	1	Catholic; Wooded, brushy areas and tallgrass prairies			Resident
San Marcos Gambusia (extirpated)	*Gambusia georgei*	0	3	0	Endemic; upper San Marcos River	LE	E	Resident
San Marcos Saddle-case Caddisfly	*Protoptila arca*	0	1	0	Swift; well-oxygenated warm water 1-2 m deep			Resident
San Marcos Salamander	*Eurycea nana*	0	2	0	Headwaters of the San Marcos River	LT	T	Resident
Spot-tailed Earless Lizard	*Holbrookia lacerata*	1	1	1	Oak-juniper woodlands and mesquite-prickly pear			Resident
Texas amorpha	*Amphoira roemeriana*	2	1	2	Plant.			Resident
Texas barberry	*Berberis swaseyi*	2	1	2	Plant.			Resident
Texas Blind Salamander	*Eurycea rathbuni*	0	3	0	Troglobitic; Caverns along 6 mile stretch of San Marcos Springs Fault	LE	E	Resident
Texas Cave Shrimp	*Palamonetes antrorum*	0	1	0	Subterranean sluggish streams and pools			Resident
Texas Garter Snake	*Thamnophis sirtalis annectens*	1	1	1	Varied, especially wet areas; bottomlands and pastures			Resident
Texas Horned Lizard	*Phrynosoma cornutum*	1	2	2	Varied, sparsely vegetated uplands		T	Resident
Texas Mock-Orange	*Philadelphus texensis*	1	1	1	Endemic; Limestone cliffs and boulders in mesic stream bottoms and canyons			Resident

Table 4C.6-1 continued

Texas Salamander	*Eurycea neotenes*	2	1	2	Salamander.			Resident
Texas Wild-Rice	*Zizania texana*	0	3	0	Upper 2.5 km of the San Marcos River	LE	E	Resident
Timber/Canebrake Rattlesnake	*Crotalus horridus*	1	2	1	Swamps, floodplains, upland pine and deciduous woodlands.		T	Resident
Warnock's Coral Root	*Hexalectris warnockii*	2	1	2	Oak-juniper woodlands in mountain canyons; terraces along creekbeds			Resident
Whooping Crane	*Grus americana*	1	3	3	Potential migrant	LE	E	Migrant
Zone-tailed Hawk	*Buteo albonotatus*	1	2	2	Arid, open country including deciduous or pine-oak woodland; nests in various habitats and sites		T	Nesting/Migrant

[1] Texas Parks and Wildlife Department (TPWD), Unpublished 2005, March 2005, Data and Map Files of the Wildlife Science Research and Diversity Division maintained by TPWD, Austin, Texas.

* LE/LT=Federally Listed Endangered/Threatened E/SA, T/SA=Federally Listed Endangered/Threatened by Similarity of Appearance C1=Federal Candidate for Listing
DL, PDL=Federally Delisted/Proposed for Delisting NL=not Federally Listed E, T=State Listed Endangered/Threatened
PE, PT=Federally Proposed Endangered/ Threatened Blank = Rare, but no regulatory listing status

program. In the case of migratory or transient species, the field survey should attempt to identify and evaluate habitat that may be attractive to migrating species, such as the threatened Zone-tailed Hawk.

The Golden-cheeked Warbler and Black-capped Vireo, both listed as endangered by USFWS are known to nest in Comal and Hays Counties in areas with appropriate habitat.[5] The Golden-cheeked Warbler and the Black-capped Vireo are upland woodland/brushland species. The fountain darter (*Etheostoma fonticola*), an endangered fish, is found only in the San Marcos and Comal Rivers and would not be affected by this project. Cagle's map turtle, a state listed threatened species, and the Guadalupe bass, the state fish, are found in the Blanco River and throughout the upper Guadalupe Basin.[6,7]

The Texas Horned Lizard, another state listed threatened species is a denizen of open, well-drained habitats with sparse cover. The decline of Texas horned lizard populations is often associated with the invasion of fireants (*Solenopsis invicta*), in addition to certain agricultural practices and urbanization, all of which are present in the Wimberley and Woodcreek areas.[8]

The threatened Blanco Blind Salamander is a troglobitic (cave-dwelling) salamander initially found in the Blanco River streambed. Other populations of this little known species may be present in the Blanco River Basin along with the Blanco River Springs salamander. Several cave arthropods have been listed within the project area. Peck's Cave amphipod, a state and federally listed endangered species, and the Long-legged cave amphipod, and Balcones cave amphipod, both species of concern are all aquatic crustaceans found in subterranean streams. In addition, the timber/canebrake rattlesnake, a state threatened species, can be found in swamps, floodplains, and deciduous woodlands throughout this area.

If the waterline to Wimberley and Woodcreek from Canyon Reservoir is assumed to mostly parallel existing roadways, it would be about 18 miles long (Figure 4C.6-1). The waterline would require a construction corridor of about 100 feet and a maintenance corridor of about 30 feet. Construction would involve the disturbance of soils and vegetation on up to 225 acres, and the long-term impacts of maintaining the right-of-way free of woody vegetation

[5] Texas Parks and Wildlife Department (TPWD), Unpublished 2005, March 2005, Data and Map Files of the Wildlife Science Research and Diversity Division maintained by TPWD, Austin, Texas.
[6] Gary P. Garrett, "Guidelines for the Management of Guadalupe Bass," TPWD, Austin, Texas, 1991.
[7] Haynes, David and Ronald R. McKown, "A New Species of Map Turtle (Genus *Graptemys)* from the Guadalupe River System in Texas," Tulane Studies in Zoology and Botany, Vol. 18, Num. 4. pp. 143-152, 1974.
[8] Price, A., W. Donaldson, and J. Morse," Final Report as Required by the Endangered Species Act, Section 6, Texas Project No. E-1-4," Texas Parks and Wildlife Department, Austin, Texas. 1993

would affect about 74 acres, including the water plant site. One major stream crossing at the Blanco River would affect an estimated half acre of this lower perennial stream during construction and require about one-tenth acre permanent easement.

The Wildlife Science Research and Diversity maps, which are maintained by TPWD, report the occurrence of endangered, threatened, or rare species near the proposed project, although there are no mapped occurrences of important species within the presently assumed general facilities layout. Reported occurrences near the project include the endangered Golden-cheeked warbler (*Dendroica chrysoparia*), four rare plant species including Texas amorpha (*Amphora roemeriana*), Warnocks Coral Root (*Hexalectris warnockii*), Glass Mountain Coral Root (*Hexalectris nitida*), and Texas Barberry (*Berberis swaseyi*), and the Texas salamander (*Eurycea neotenes*).

Resource conflicts can generally be avoided or minimized by careful site and alignment selection, avoiding, for example, springs and vegetated wetlands where the pipeline crosses a stream channel, and mesic, wooded slopes. The Blanco blind salamander, fountain darter, Golden-cheeked Warbler and Black-capped Vireo are the endangered species most likely to be in conflict with portions of this water management strategy, but potential conflicts may be avoidable by selecting an alternative pipeline route. In addition to the birds, any future detailed assessment should include a complete review for springs and karst associated species and other important species with appropriate habitat. Where right-of-way clearing and construction activity cannot avoid affecting a federally protected species, consultation with the USFWS concerning the need for a permit for the incidental take of that species should be conducted.

Cultural resources protection on public lands in Texas is afforded by the Antiquities Code of Texas (Title 9, Chapter 191, Texas Natural Resource Code of 1977), the National Historic Preservation Act (Pl96-515), and the Archeological and Historic Preservation Act (PL93-291). Based on the review of available records housed at the Texas Archeological Research Laboratory in Austin, six cultural resource sites appear to occur within the proposed project area. Table 4C.6-2 lists the archeological sites within a one-mile corridor of the proposed project area. Considering that the owner or controller of the project will likely be a political subdivision of the State of Texas (i.e. river authority, municipality, county, etc.), they will be required to coordinate with the Texas Historical Commission regarding if the project will affect waters of the United States or wetlands, the project sponsor will also be required to coordinate with the U.S. Army Corps of Engineers regarding impacts to cultural resources.

Table 4C.6-2
Previously recorded sites within One-Mile corridor of the proposed pipeline for Canyon Reservoir.

Sites	41CM7
	41CM206
	41HY10
	41HY137
	41HY369
	41HY379

4C.6.4 Engineering and Costing

For this water management strategy, surface water supply for the Wimberley/Woodcreek area would be supplied from a treatment plant near Canyon Reservoir on a wholesale basis to existing water utilities in the service area. The facilities required for this water management strategy would include a raw water intake on Canyon Reservoir, a raw water pipeline, water treatment plant, and treated water pump station near Canyon Reservoir, a treated water transmission line from the plant to Wimberley/Woodcreek, and a terminal reservoir located near Wimberley and Woodcreek.

For purposes of costing and general environmental assessment of this water management strategy, a surface water intake site is shown on Figure 4C.6-1 in the general vicinity of the north end of Canyon Dam. From the intake, raw water would be pumped to a treatment plant located within one mile of the intake. From the treatment plant, a 24-inch treated water transmission pipeline to the Wimberley and Woodcreek area would be required. Both the water treatment plant and the transmission pipeline are sized to meet peak daily demands estimated at twice the average daily demands. To treat the water from Canyon Reservoir, either a membrane filtration plant or a modular facility employing high-rate clarification with filtration could be used. The facilities serving Wimberley/Woodcreek have been sized for delivery of year 2060 needs of 4,636 acft/yr. The intake, treatment plant, and finished water pump station are sized for 8.3 MGD with a 24-inch pipeline from the plant to Wimberley and a 20-inch pipeline delivers water to Woodcreek and Woodcreek Utilities.

Table 4C.6-3 provides a cost summary for the Wimberley and Woodcreek water supply from Canyon Reservoir. The operating cost for this water management strategy was calculated for a total static lift of 146 feet and an annual delivery of 4,636 acft to Wimberley and Woodcreek. Financing the construction and associated capital costs were calculated at a 6.0 percent annual interest rate, with a repayment period of 30 years. The annual cost of water purchased from GBRA was assumed to be $88 per acft. Total annual costs, including debt repayment, interest, and operation and maintenance, are $4,583,000. For an annual delivery of 4,636 acft, the resulting annual unit cost of water is $989 per acft, or $3.03 per 1,000 gallons (Table 4C.6-3). This is the cost of treated water delivered on a wholesale basis and does not include the operating cost of the distribution system.

4C.6.5 Implementation Issues

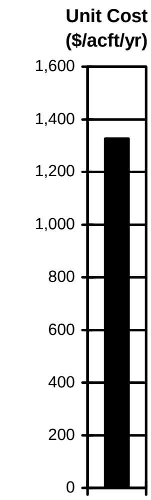
Requirements Specific to Treatment and Transmission

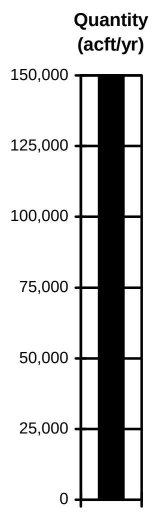
1. Necessary permits:
   a. USACE Sections 10 and 404 dredge and fill permits for intake at Canyon Reservoir and stream crossings.
   b. TCEQ discharge of water treatment plant settling basin blowdown and filter backwash.
   c. GLO Sand and Gravel Removal permits.
   d. TPWD Sand, Gravel, and Marl permit for river crossing.
2. Right-of-way and easement acquisition.
3. Crossings:
   a. Highways
   b. Creeks and river
   c. Other utilities
4. Financing:
   a. Sponsoring entity must be identified and be able to incur debt to finance project.
   b. Participating entities must negotiate water purchase contract with GBRA and establish rate structures.

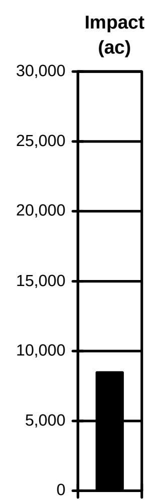
Table 4C.6-3.
Cost Estimate Summaries for Wimberley and Woodcreek Water Supply from Canyon Reservoir (Second Quarter 2002 Prices)

Item	***Estimated Cost***
Capital Costs	
Intake and Pump Station (8.3 MGD)	$3,796,000
Transmission Pipeline (24-inch dia. for 14 miles and 20-inch dia. for 4 miles)	$10,040,000
Water Treatment Plant (8.3 MGD)	$11,469,000
Distribution & Storage Tanks	$590,000
Total Capital Cost	**$25,895,000**
Engineering, Legal Costs and Contingencies	$8,561,000
Environmental & Archaeology Studies and Mitigation	$462,000
Land Acquisition and Surveying (74 acres)	$639,000
Interest During Construction (1 year)	$1,423,000
Total Project Cost	**$36,980,000**
Annual Costs	
Debt Service (6 percent, 30 years)	$2,687,000
Operation and Maintenance	
Intake, Pipeline, Pump Station	$201,000
Water Treatment Plant	$902,000
Pumping Energy Costs (6,418,066 kW-hr @ 0.06 $/kW-hr)	$385,000
Purchase of Water (4,636 acft/yr @ 88 $/acft)	$408,000
Total Annual Cost	**$4,583,000**
Available Project Yield (acft/yr)	4,636
Annual Cost of Water ($ per acft)	$989
Annual Cost of Water ($ per 1,000 gallons)	$3.03
Notes: Facilities sized to meet peak day demands assuming a peaking factor of 2.0 times average day demand.	

2006 South Central Texas Regional Water Plan
Water Management Strategy Summary Sheet







Name: **LCRA-SAWS Water Project (LSWP) – Bay City to Bexar County**

Description: This management strategy is based on a Definitive Agreement between SAWS and LCRA, signed in 2002, for the purchase of up to 150,000 acft/yr of surface water from the Lower Colorado River Basin. The amount of water delivered from Bay City to Bexar County is assumed to be 150,000 acft/yr. Facilities include intakes, pump stations, off-channel storage facility of 250,000 acft; a primary intake and pump station; an 90-inch 161-mile transmission pipeline to the Twin Oaks WTP with 4 booster stations; a water treatment plant (expansion or new) at the Twin Oaks property in Southern Bexar County; and system improvements for integration of the additional supply. Facility locations are subject to change.

***Decade Needed*:** 2040 – 2050

Cost, Quantity of Water, and Land Impacted

Unit Cost of Water:	**$1,326**	**$/acft/yr**	**Treated Water Delivered**
Quantity of Water:	**150,000**	**acft/yr**	**Reliability = Firm**
Land Impacted:	**8,468**	**acres**	

Additional Considerations per Regional Water Planning Guidelines

Environmental Factors:

Potential concerns with endangered species, habitat, cultural resources, and TPWD Ecologically Unique Stream Segments. Endangered species include the Attwater's Prairie Chicken, Eskimo Curlew, Jaguarundi, & Ocelot. Pipeline could come in close proximity to a Bald Eagle rookery in Jackson County.

Impacts on Water Resources:

Reductions in freshwater inflows to Matagorda Bay associated with greater utilization of existing water rights and new appropriation. Potential effects of these reductions are being studied by LCRA & SAWS. Significant additional groundwater production for agricultural use and associated reductions in local and regional groundwater levels.

Impacts on Agricultural & Natural Resources:

There are potential increases in reliable water supply for irrigation and improved irrigation efficiency in Region K. Off-channel reservoirs will inundate approximately 6,750 acres in Matagorda County.

Other Relevant Factors per SCTRWPG:

Encourages beneficial use of available rights. Protects instream flows and recreational opportunities through lower basin diversion. Equitable cost sharing for development of water supplies in Region K and Region L. Point of diversion is the subject of on-going studies, however, the Bay City diversion point used in the 2001 South Central Texas Regional Water Plan has been assumed for cost estimation purposes. Allocation of the full projected 150,000 acft/yr to this potential diversion location does not preclude development of an upstream alternative or additional diversion location.

Comparison of Strategies to Meet Needs:

Moderate to high unit cost. No conflicts with other recommended water management strategies.

Interbasin Transfer Issues:

An amendment to the existing LCRA permits for the interbasin transfer of this water would be required. Environmental flow constraints limiting diversions under the existing water rights may be added during the amendment process thereby reducing the dependable supply and increasing the unit cost of water.

Third-Party Impacts of Voluntary Transfers:

Potential benefits to Lower Colorado River Basin irrigation interests in Region K.

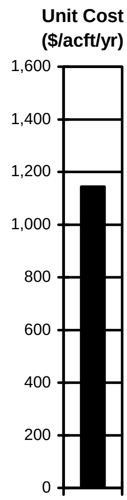
Regional Efficiency:

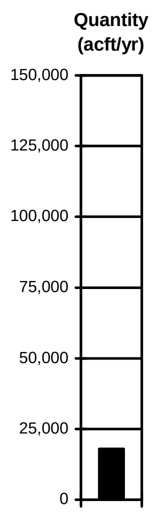
Shared pipeline alignment with other recommended water management strategies. Potential for shared water treatment and balancing storage facilities in Bexar County.

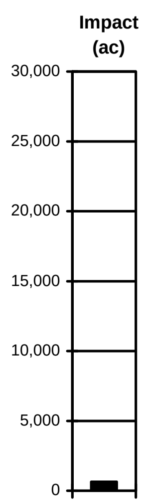
Water Quality Considerations:

None of significant concern.

2006 South Central Texas Regional Water Plan
Water Management Strategy Summary Sheet







Name: **LCRA-SAWS Water Project (LSWP) – Bastrop to Hays County**

Description: This water management strategy is based on the delivery of 18,000 acft/yr of water to Hays County from the Colorado River near Bastrop. Facilities include an intake, pump station, off-channel reservoir, and a water treatment plant in Bastrop County; a primary intake and pump station; a 30-inch 35-mile transmission pipeline to Hays County; and distribution system improvements for integration of the additional supply.

***Decade Needed*:** 2020 – 2030

Cost, Quantity of Water, and Land Impacted

Unit Cost of Water:	**$1,144**	**$/acft/yr**	**Treated Water Delivered**
Quantity of Water:	**18,000**	**acft/yr**	**Reliability = Firm**
Land Impacted:	**651**	**acres**	

Additional Considerations per Regional Water Planning Guidelines

Environmental Factors:
Project area may include Houston Toad habitat.

Impacts on Water Resources:
Reductions in freshwater inflows to Matagorda Bay associated with greater utilization of existing water rights. Potential effects of these reductions are being studied by LCRA & SAWS.

Impacts on Agricultural & Natural Resources:
There are potential increases in reliable water supply for irrigation and improved irrigation efficiency in Region K. Off-channel reservoir will inundate approximately 500 acres in Bastrop County.

Other Relevant Factors per SCTRWPG:
Encourages beneficial use of available rights. Equitable cost sharing for development of water supplies in Region K and Region L. Very limited interests in this water supply expressed by entities in Hays and Caldwell Counties.

Comparison of Strategies to Meet Needs:
Moderate to high unit cost. No conflicts with other recommended water management strategies.

Interbasin Transfer Issues:
An amendment to the existing LCRA permits for the interbasin transfer of this water would be required. Environmental flow constraints limiting diversions under the existing water rights may be added during the amendment process.

Third-Party Impacts of Voluntary Transfers:
Potential benefits to Lower Colorado River Basin irrigation interests in Region K.

Regional Efficiency:
Reductions in channel loss due to diversion in Bastrop County rather than diversion in Matagorda County.

Water Quality Considerations:
None of significant concern.

4C.9 LCRA-SAWS Water Project (LSWP)

4C.9.1 Description of Water Management Strategy

The Lower Colorado River Authority – San Antonio Water System (LCRA-SAWS) Water Project (LSWP) involves the conservation and development of approximately 330,000 acft/yr in the Lower Colorado River Basin Counties of Matagorda, Wharton, and Colorado. Of that 330,000 acft/yr, LCRA has made up to 150,000 acft/yr available to the San Antonio Water System (SAWS), for an 80-year period. In 2002, SAWS signed a Definitive Agreement with LCRA for the purchase and use of this water. The LSWP involves the potential future diversion of water from the Colorado River, development of off-channel storage, and conveyance through a transmission pipeline to the Twin Oaks Water Treatment Plant (WTP) site in south Bexar County. Water would then be treated and integrated into municipal supply systems in and around the City of San Antonio.

The configuration of the LSWP water management strategy is still being studied. Diversion points along the Colorado River from Colorado County to Bay City in Matagorda County are under consideration at this time. In addition, a diversion point near Bastrop could be used to deliver a portion of the 150,000 acft/yr to entities with needs in Caldwell and Hays Counties as recommended in the 2001 South Central Texas Regional Water Plan. The delivery point of the LSWP water is most likely the Twin Oaks WTP site in south Bexar County, however, a secondary delivery point in northeast Bexar County is also under consideration. As LCRA requested that the point of diversion for this water management strategy be Bay City for the 2001 South Central Texas Regional Water Plan, this point of diversion has been retained for cost estimation purposes in the 2006 Regional Water Plan. The Colorado River diversion locations and conceptual pipeline routes for the Bay City and Bastrop diversion locations are shown in Figures 4C.9-1 and 4C.9-2, respectively. Facility locations for the LSWP are approximate and will be determined upon further study by LCRA, SAWS, and their consultants (including CH2MHill[1,2]).

[1] CH2MHill, "Project Viability Assessment," Lower Colorado River Authority, November 2004
[2] CH2MHill, "2005 Project Viability Assessment," Lower Colorado River Authority, October 2005

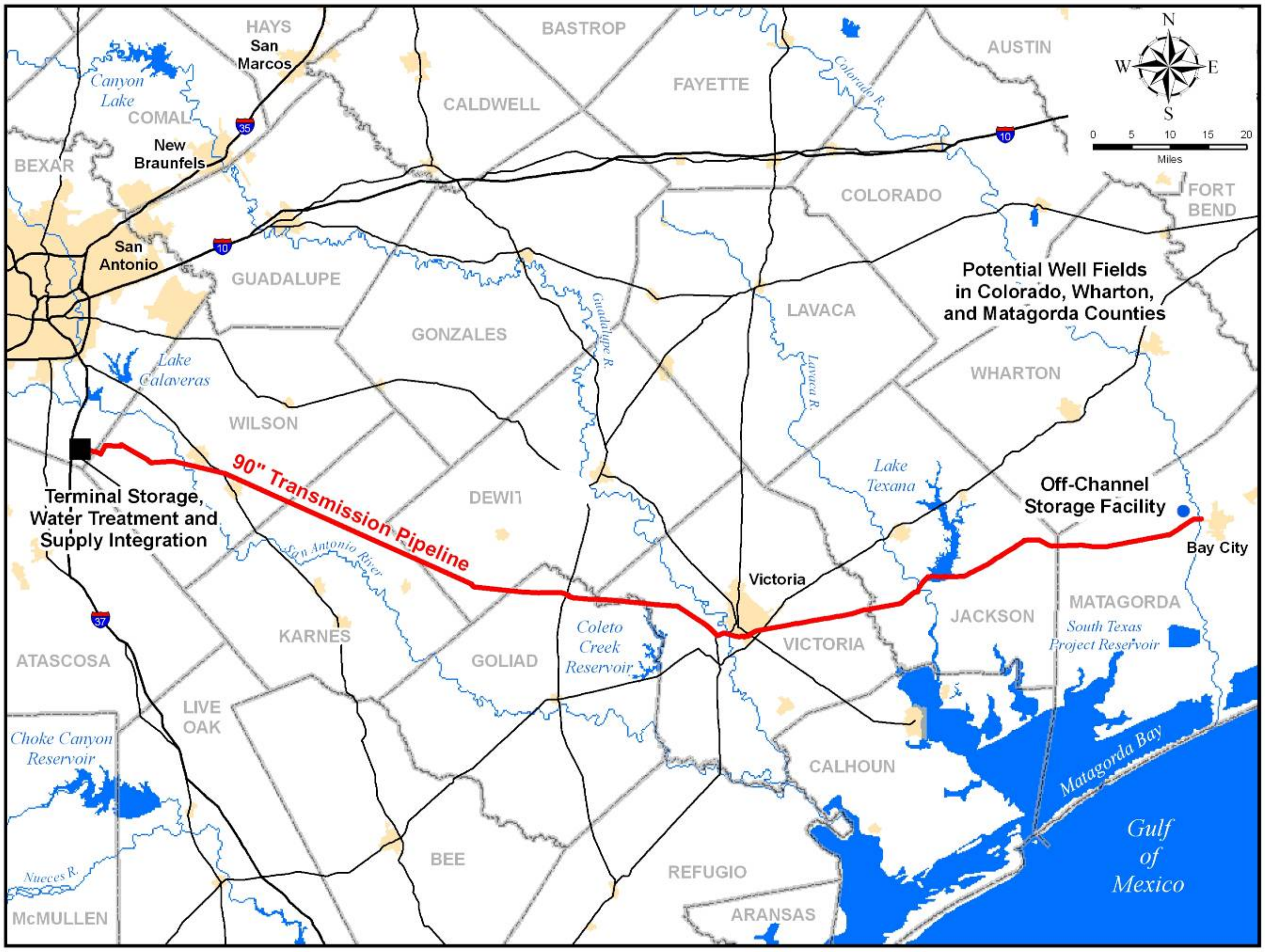


Figure 4C.9-1. LCRA-SAWS Water Project – Bay City to Bexar County (Facility Locations Subject to Change)

4C.9.2 Available Yield

Sources of water for the LSWP include presently under-utilized surface water rights, stored water from the Highland Lakes System, and new surface water appropriations. In order to meet local irrigation needs, various water conservation measures and periodic utilization of groundwater from the Gulf Coast Aquifer will be necessary. The Gulf Coast Aquifer groundwater will be used conjunctively with LCRA surface water rights to meet the needs of in-district farmers and will not be exported as part of the LSWP. LCRA has explored several combinations of these water supplies that could be used to ensure the availability of a dependable

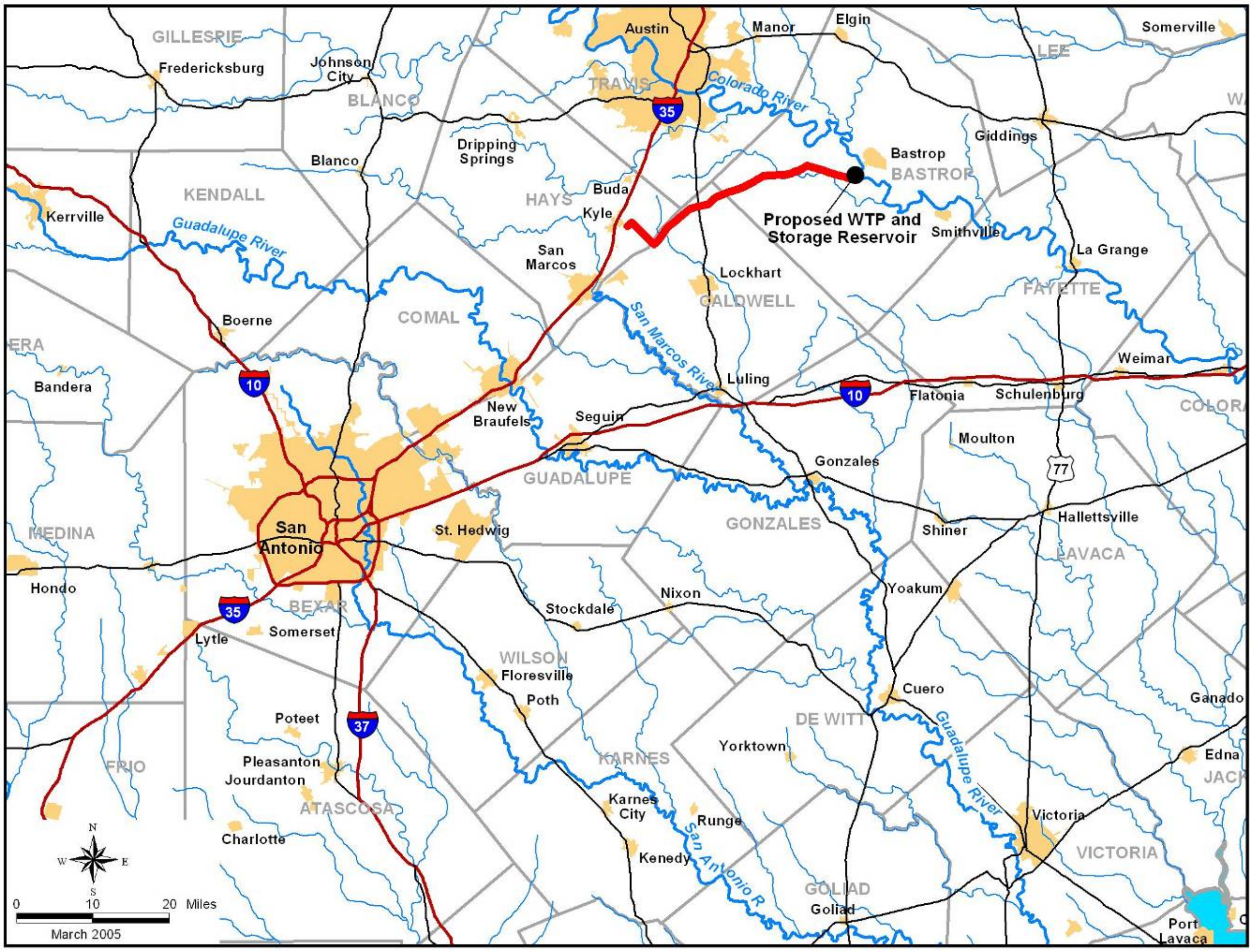


Figure 4C.9-2. LCRA-SAWS Water Project – Bastrop to Hays County

supply of 150,000 acft/yr to SAWS. While no final determination has been made to-date, one potential scenario for utilization of potential sources (provided by R.J. Brandes Company on behalf of LCRA and SAWS) is shown in Figure 4C.9-3 which summarizes simulated diversions from the Colorado River (in Colorado County) into off-channel storage. Figure 4C.9-4 illustrates the total storage in Lakes Travis and Buchanan of the LCRA Highland Lakes System with and without the project. With the LSWP, the minimum storage in the system increases from about 9,000 acft to about 211,000 acft and system storage is greater in approximately 72% of the months. Monthly long-term and drought average freshwater inflows for Matagorda Bay with and without implementation of the LSWP are illustrated in Figures 4C.9-5 and 4C.9-6,

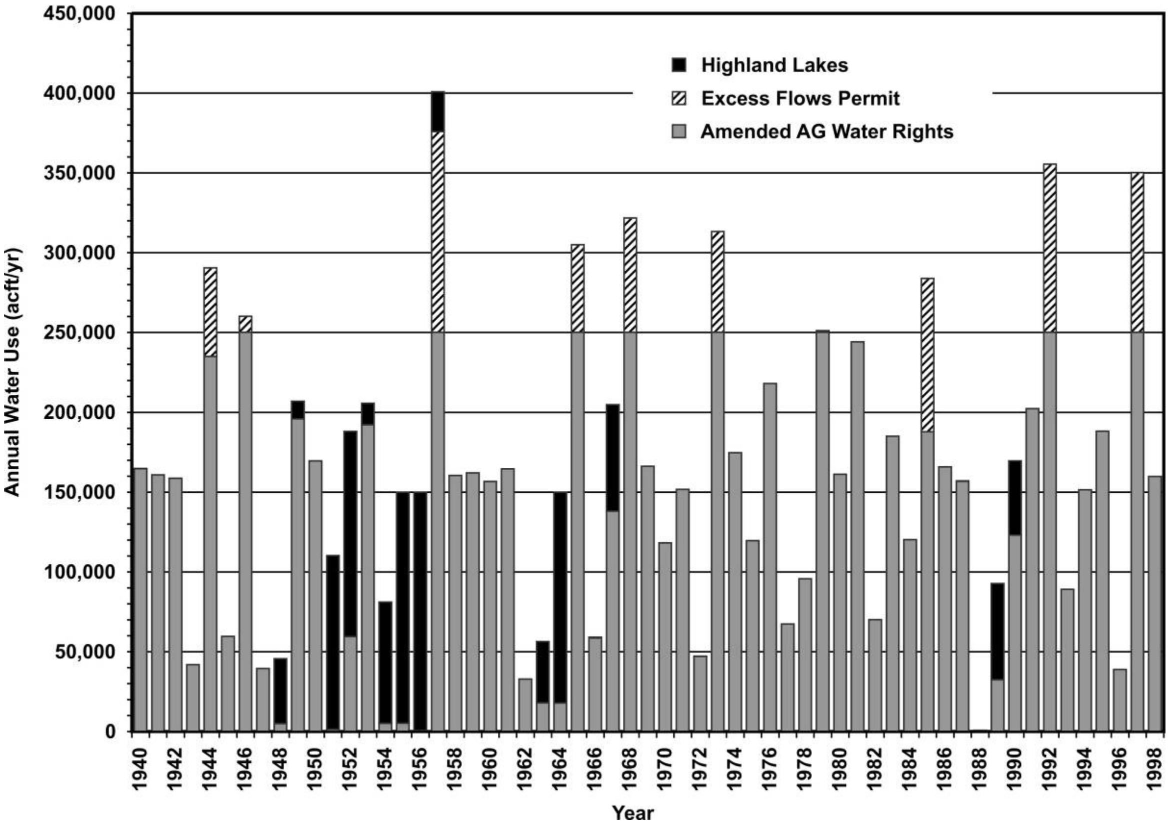


Figure 4C.9-3. LCRA-SAWS Water Project – Potential Water Supply Sources

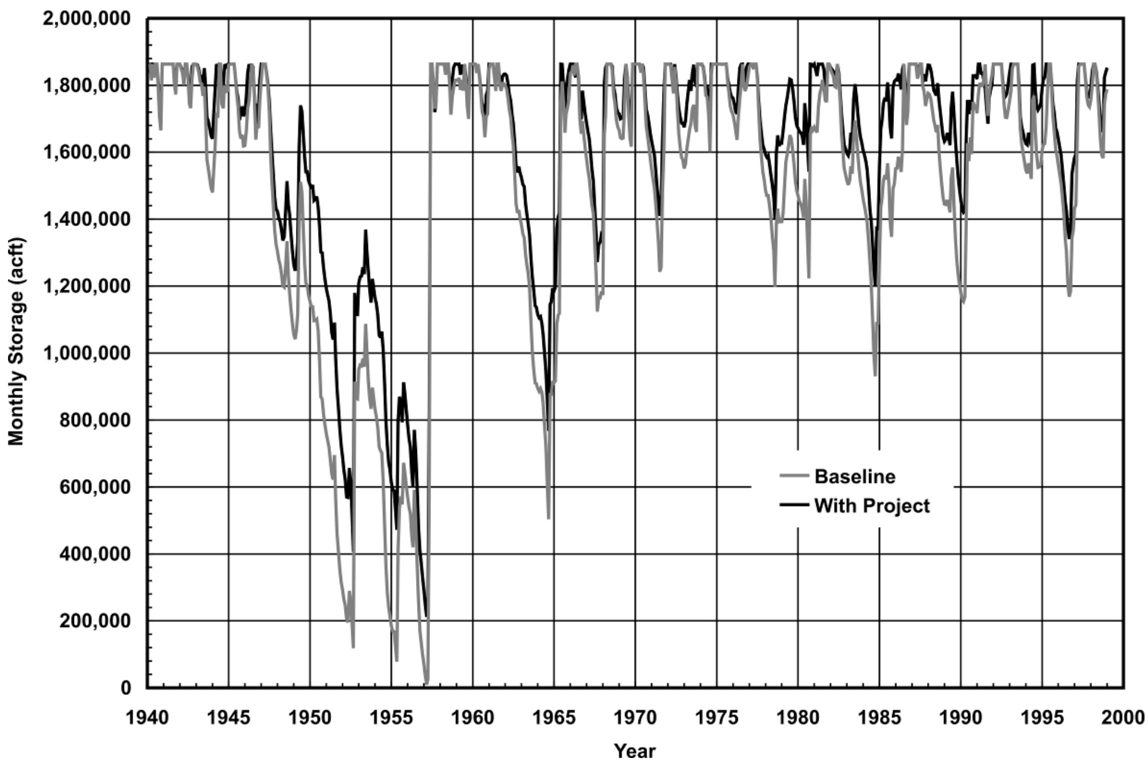


Figure 4C.9-4. LCRA-SAWS Water Project – Simulated Monthly Storage of LCRA System

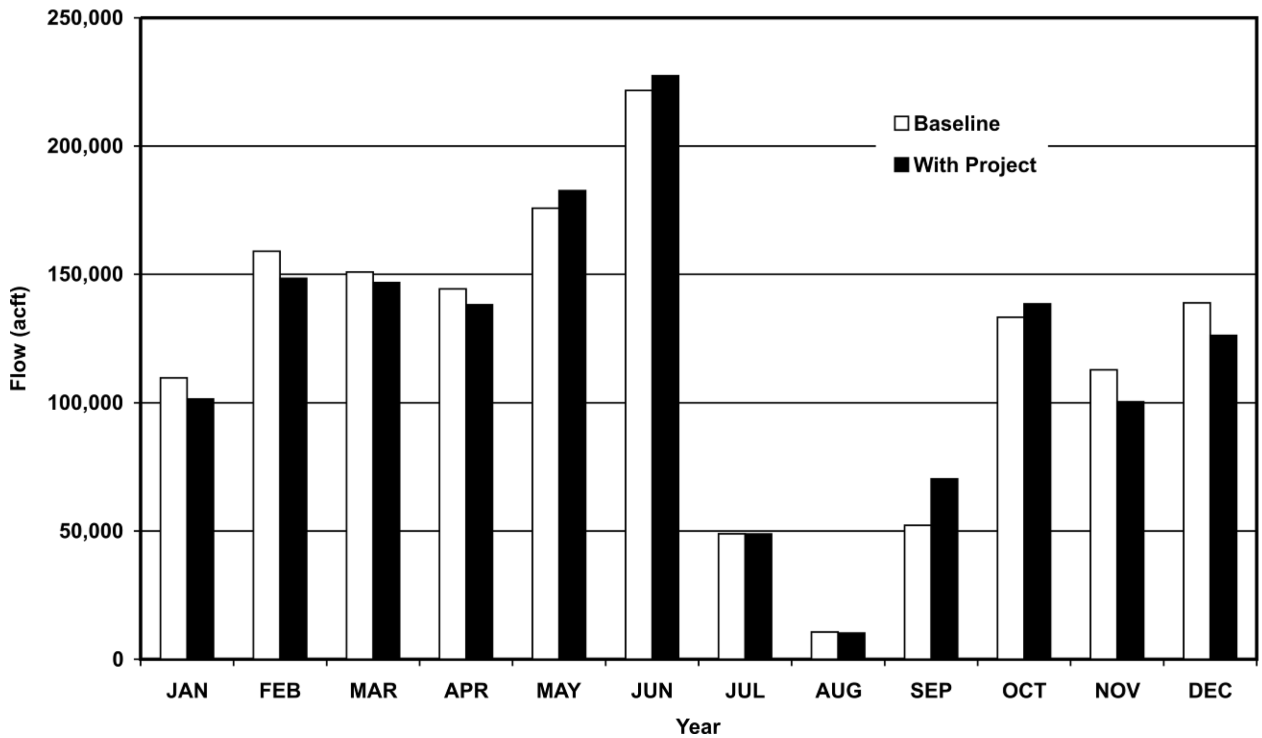


Figure 4C.9-5. LCRA-SAWS Water Project – Simulated Monthly Long-term Average Inflows to Matagorda Bay

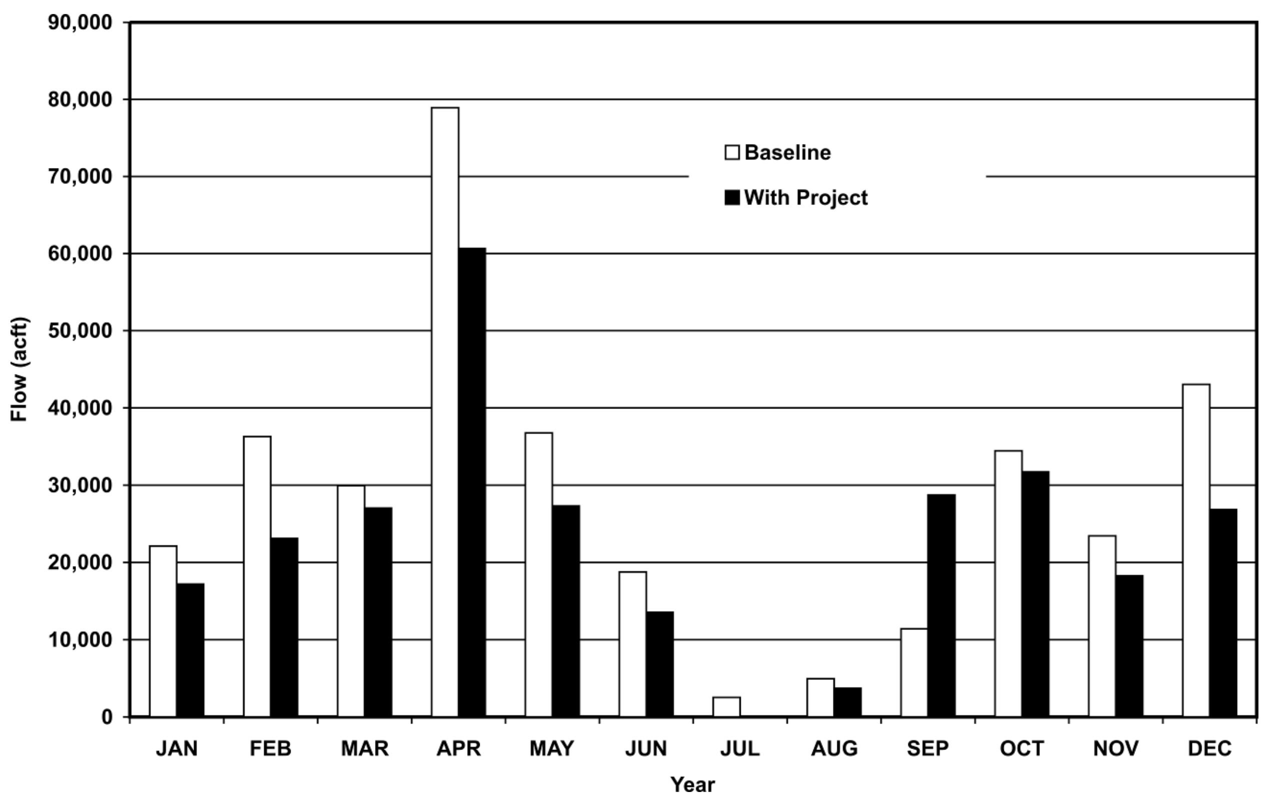


Figure 4C.9-6. LCRA-SAWS Water Project – Simulated Monthly Drought Average Inflows to Matagorda Bay

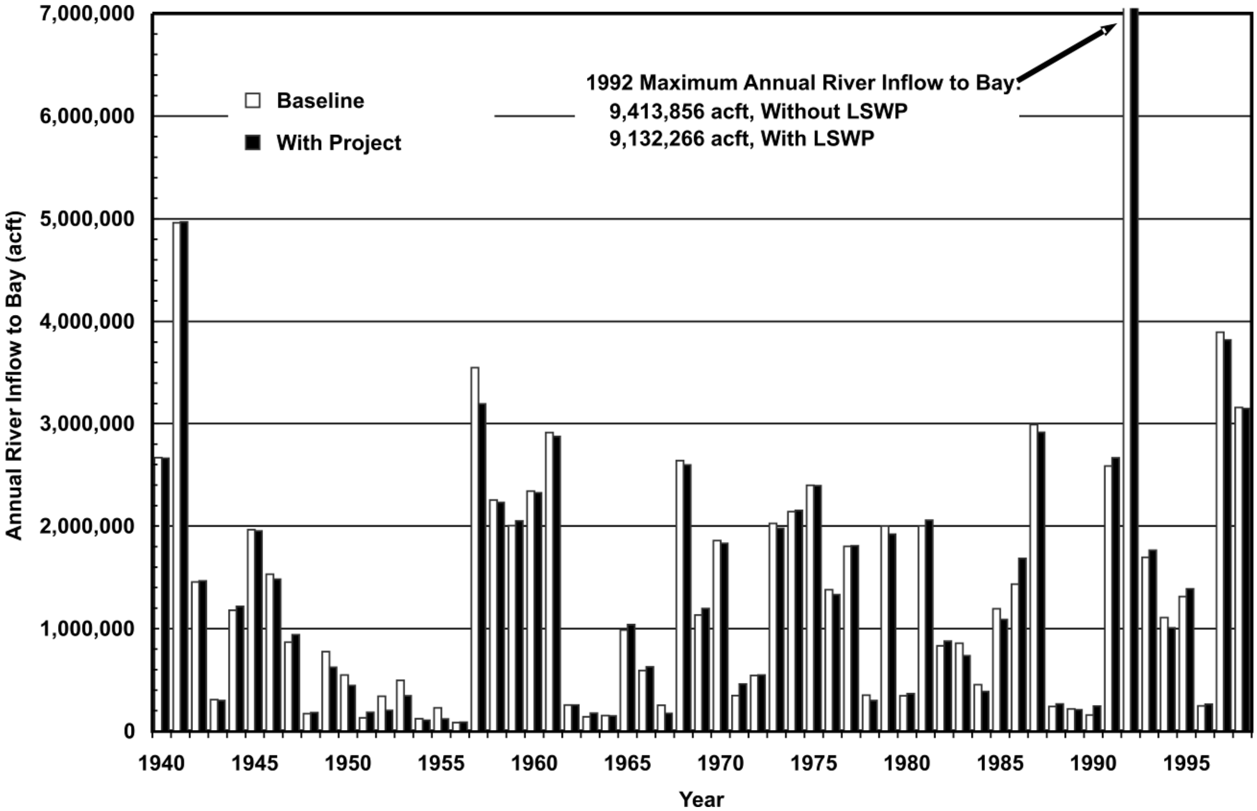


Figure 4C.9-7. LCRA-SAWS Water Project – Simulated Annual Inflows to Matagorda Bay

respectively. The largest long-term average decrease is 18,594 acft/month in December. The largest long-term average increase is 18,178 acft/month in September. Figure 4C.9-7 shows simulated annual inflows to Matagorda Bay for each year of the 1940-1998 simulation period. It is important to note that figures showing sources of water, lake levels, and streamflow changes have been provided by LCRA, SAWS, and their consultant(s). For more information on modeling assumptions, baseline conditions, and system operation, please contact LCRA or SAWS.

4C.9.3 Environmental Issues

This strategy is based on an agreement between SAWS and LCRA and involves the purchase of up to 150,000 acft/yr of surface water from the Lower Colorado River Basin. Facilities in this plan include intakes, pump stations, and a 250,000 acft off-channel storage facility potentially located in Colorado, Wharton, or Matagorda County, a 161-mile long transmission pipeline to Bexar County, transmission booster stations, terminal storage, and expansion of the water treatment plant in Bexar County.

The water transmission pipeline between Bay City and the Twin Oaks Water Treatment Plant in Bexar County would be approximately 161 miles long[3]. The construction of the pipeline would include the clearing and removal of woody vegetation. The proposed pipeline route would traverse three of Omernik's[4] ecoregions: the Western Gulf Coastal Plain, the East Central Texas Plains, and the westernmost reaches of the Texas Blackland Prairie. These areas include the Tamaulipan and Texan biotic provinces.[5] A small central section of the pipeline corridor would traverse the Post Oak Savannah vegetational area, but the longest segments would be in the South Texas Plains and Coastal Prairies vegetational areas.[6] The climax vegetation of these three vegetational areas is considered to be post oak or live oak savannah and grassland, but much of the area presently consists of rangeland, small farms, and brushland, with woodlands tending to occur as remnant riparian strips.[7] In addition, the Guadalupe River, Arenosa Creek, and Garcitas Creek, all crossed by the transmission pipeline to Bexar County are listed by TPWD as an Ecologically Significant River and Stream Segments.

Plant and animal species in the project area listed by the USFWS, and TPWD as endangered or threatened are presented in Table 4C.9-1. All species listed have habitat requirements or preferences that suggest they could be present within the project area. Surveys for protected species should be conducted within the proposed construction corridors where preliminary evidence indicates their existence. Many of these species, such as the Texas Tortoise, the Texas Horned Lizard, and the Indigo Snake, are dependent on shrubland or riparian habitat. The Texas Garter Snake may be present in wetland habitat, and the Timber Rattlesnake, a threatened species, may be found in the riparian woody vegetation of the area. Destruction of potential habitat can be avoided by selecting a corridor through previously disturbed areas, such as croplands. Selection of a pipeline right-of-way alongside the existing habitat could also be beneficial to some wildlife by providing edge habitat; however, the majority of these areas are small and fragmented, so care should be taken to ensure minimum impacts.

---

[3] Ibid.
[4] Omernik, J.M., "Ecoregions of the Conterminous United States," Annals of the Association of American Geographers, 77:118-125, 1987.
[5] Blair, W. Frank, "The Biotic Provinces of Texas," Texas Journal of Science 2(1):93-117, 1950.
[6] Gould, F. W., "The Grasses of Texas," Texas A&M University Press, College Station, Texas, 1975.
[7] Ibid.

Table 4C.9-1.
Important Species* Having Habitat or Known to Occur in Counties Potentially Affected by the LCRA-SAWS Water Project

Common Name	Scientific Name	Impact Value	Multiplier Based on Status	Adjusted Impact	Summary of Habitat Preference	Listing Entity		Potential Occurrence in County
						USFWS[1]	TPWD[1]	
American Eel	*Anguilla rostrata*	1	1	1	Moist aquatic habitats.			Resident
American Peregrine Falcon	*Falco peregrinus anatum*	0	3	0	Open country; cliffs	DL	E	Nesting/ Migrant
Arctic Peregrine Falcon	*Falco peregrinus tundrius*	0	2	0	Open country; cliffs	DL	T	Nesting/Migrant
Atlantic Hawksbill Sea turtle	*Eretmochelys imbricata*	1	3	3	Gulf and bay system.	LE	E	Migrant
Attwater's Greater Prairie-Chicken	*Tympanuchus cupido attwateri*	2	3	6	Coastal Prairies of Gulf Coastal Plain	LE	E	Nesting
Bald Eagle	*Haliaeetus leucocephalus*	2	2	4	Large Bodies of water with nearby resting sites	LT-PDL	T	Nesting/Migrant
Big Red Sage	*Salvia penstemonoides*	2	1	2	Moist Creek and stream bed edges; historic; introduced in native plant nursery trade			Resident
Black Bear	*Usus americanus*	0	2	0	Mountains, broken country, woods, brushlands, forests	T/SA; NL	T	Resident
Black-capped Vireo	*Vireo atricapillus*	0	3	0	Semi-open broad-leaved shrublands	LE	E	Nesting/Migrant
Black-Spotted Newt	*Notophthalmus meridionalis*	1	2	2	Ponds and resacas in south Texas		T	Resident
Brown Pelican	*Pelecanus occidentalis*	0	3	0	Coastal inlands for nesting, shallow gulf and bays for foraging	LE	E	Nesting/Migrant
Cave Myotis Bat	*Myotis velifer*	0	1	0	Roosts colonially in caves.			Resident

Table 4C.9-1 continued

Bracted Twistflower	*Streptanthus bracteatus*	1	1	1	Endemic; Shallow clay soils over limestone; rocky slopes			Resident
Cagle's Map Turtle	*Graptemys caglei*	1	2	2	Endemic, Guadalupe River System.	C1	T	Resident
Correll's False Dragon-Head	*Physostegia correllii*	1	1	1	Wet soils			Resident
Coastal Gay Feather	*Liatris bracteata*	2	1	2	Black clay soils of midgrass grasslands on coastal prairie remnants.			Resident
Corkwood	*Leitneria floridana*	1	1	1	Small shrub, found in narrow zone between brackish marsh and freshwater areas.			Resident
Elmendorf's Onion	*Allium elmendorfii*	1	1	1	Endemic; deep sands derived from Queen City and similar Eocene formations			Resident
Creeper (Squawfoot)	*Strophitus undulatus*	1	1	1	small to large streams, prefers gravel or gravel and mud in flowing water; Colorado, Guadalupe, San Antonio, Neches (historic), and Trinity (historic) River basins			Resident
Eskimo Curlew	*Numenius borealis*	1	3	3	Grasslands, pastures.	LE	E	Nonbreeding Resident
Golden-Cheeked Warbler	*Dendroica chrysoparia*	1	3	3	Woodlands with oaks and old juniper	LE	E	Nesting/Migrant
Green Sea Turtle	*Chelonia mydat*	1	2	2	Gulf and bay system.	LT	T	Migrant
Guadalupe Bass	*Micropterus treculi*	2	1	2	Clear flowing streams			Resident
Gulf Saltmarsh Snake	*Nerodia clarkii*	0	1	0	Brackish to saline coastal waters			Resident
Guadalupe Darter	*Percina sciera apristis*	1	1	1	Raceways of medium streams and rivers.			
Henslow's Sparrow	*Ammodramus henslowii*	1	1	1	Weedy fields, cut over areas; bare ground for running and walking			Nesting/Migrant
Indigo Snake	*Drymarchon corais erebennus*	1	2	2	Grass prairies and sand hills; usually thornbush woodland and mesquite savannah of coastal plain		T	Resident
Interior Least Tern	*Sterna antillarum athalassos*	1	3	3	Inland river sandbars for nesting and shallow water for foraging	LE	E	Nesting/Migrant
Jaguarundi	*Felis yagouaroundi*	0	3	0	South Texas thick brushlands, favors areas near water	LE	E	Resident
Kemp's Ridley Sea Turtle	*Lepidochelys kempii*	1	3	3	Gulf and bay system.	LE	E	Migrant
Keeled Earless Lizard	*Holbrookia propinqua*	1	1	1	Coastal dunes, Barrier islands and sandy areas			Resident
Leatherback Sea Turtle	*Dermochelys coriacea*	1	3	3	Gulf and bay system.	LE	E	Migrant

Table 4C.9-1 continued

Loggerhead Sea Turtle	*Caretta caretta*	1	2	2	Gulf and bay system.	LT	T	Migrant
Louisiana Black Bear	*Ursus americanus luteolus*	0	2	0	Within historical range.	LT	T	
Maculated Manfreda Skipper	*Stallingsia maculosus*	1	1	1	Fast erratic flight, larvae feed inside a leaf shelter, pupate in cocoon made of leaves & silk			Resident
Mountain Plover	*Charadrius montanus*	1	1	1	Non-breeding-shortgrass plains and fields, plowed fields and sandy deserts			Nesting/Migrant
Ocelot	*Felis pardalis*	1	3	3	Dense chaparral thickets; mesquite-thorn scrub and live oak mottes	LE	E	Resident
Parks' Jointweed	*Polygonella parksii*	2	1	2	South Texas Plains; subherbaceous annual in deep loose sands, spring-summer			Resident
Piping Plover	*Charadrius melodus*	0	2	0	Beaches and flats of Coastal Texas	LT	T	Migrant
Pistolgrip	*Tritogonia verrucosa*	1	1	1	stable substrate, rock, hard mud, silt, and soft bottoms, often buried deeply; east and central Texas, Red through San Antonio River basins			Resident
Plains Gumweed	*Grindelia oolepsis*				Early successional patches in coastal prairie on heavy clay soils, sometimes in disturbed habitats in urban areas			Resident
Plains Spotted Skunk	*Spilogale putorius interrupta*	1	1	1	Prefers wooded, brushy areas and tallgrass prairie, fields, prairies, croplands, fence rows, forest edges			Resident
Red Wolf	*Canis rufus*	0	3	0	Extirpated.	LE	E	
Reddish Egret	*Egretta rufescens*	0	2	0	Coastal inlands for nesting, coastal marshes for foraging		T	Migrant
Runyon's Water Willow	*Justicia runyonii*	1	1	1	Openings in subtropical woodlands.			Resident
Rock-pocketbook	*Arcidens confragosus*	1	1	1	mud, sand, and gravel substrates of medium to large rivers in standing or slow flowing water, may tolerate moderate currents and some reservoirs, east Texas, Red through Guadalupe River basins			Resident
Sandhill Woolywhite	*Hymenopappus carrizoanus*	2	1	2	Endemic; Open areas in deep sands derived from Carrizo and similar Eocene formations			Resident
Sheep Frog	*Hypopachus variolosus*	1	2	2	Deep sandy soils of Southeast Texas		T	Resident
Smooth Green Snake	*Liochlorophis vernalis*	0	2	0	Gulf Coastal Plain; mesic coastal shortgrass prairie vegetation; prefers dense vegetation		T	Resident

Table 4C.9-1 continued

Smooth Pimpleback	*Quadrula houstonensis*	1	1	1	small to moderate streams and rivers as well as moderate size reservoirs; mixed mud, sand, and fine gravel, tolerates very slow to moderate flow rates, appears not to tolerate dramatic water level fluctuations, scoured bedrock substrates, or shifting sand bottoms, lower Trinity (questionable), Brazos, and Colorado River basins			Resident
Snowy Plover	*Charadrius alexandrinus*	0	1	0	Wintering Migrant on mud flats.			Migrant
Sooty Tern	*Sterna fuscata*	1	2	2	Catches small fish.			Resident
South Texas Siren (Lg. Form)	*Siren sp. 1*	1	2	2	Moist soils		T	Resident
Spot-Tailed Earless Lizard	*Holbrookia lacerata*	1	1	1	central & southern Texas; oak-juniper woodlands and mesquite-prickly pear			Resident
Texas Asaphomyian Tabanid Fly	*Asaphomyia texanus*	1	1	1	Found near slow-moving water, eggs laid on objects near water; larvae are aquatic, adults prefer shady areas; feed on nectar and pollen			Resident
Texas Diamondback Terrapin	*Malaclemys terrapin littoralis*	0	1	0	Bays, coastal marshes of the upper two-thirds of Texas Coast			Resident
Texas Fatmucket	*Lampsilis bract eata*	1	1	1	streams and rivers on sand, mud, and gravel substrates; intolerant of impoundment; broken bedrock and course gravel or sand in moderately flowing water; Colorado and Guadalupe River basins			Resident
Texas Fawnsfoot	*Truncilla macrodon*				little known; possibly rivers and larger streams, and intolerant of impoundment; flowing rice irrigation canals, possibly sand, gravel, and perhaps sandy-mud bottoms in moderate flows; Brazos and Colorado River basins			
Texas Garter Snake	*Thamnophis sirtalis annectens*	1	1	1	Varied, especially wet areas; bottomlands and pastures			Resident
Texas Horned Lizard	*Phrynosoma cornutum*	1	2	2	Varied, sparsely vegetated uplands, grass, cactus, brush		T	Resident
Texas Tortoise	*Gopherus berlandieri*	1	2	2	Open brush w/ grass understory; open grass/bare ground avoided; occupies shallow depressions at base of bush or cactus, underground burrows, under objects; active March through November		T	Resident
Threeflower broomweed	*Thurovia triflora*	1	1	1	Endemic, black clay soils.			Resident

Table 4C.9-1 continued

Timber Rattlesnake	*Crotalus horridus*	1	2	2	Floodplains, upland pine, deciduous woodlands, riparian zones, abandoned farms, dense ground cover		T	Resident
Welder Machaeranthera	*Psilactis heterocarpa*	2	1	2	Coastal prairie; Shrub-infested grasslands and open mesquite-huisache woodlands			Resident
Two-flower Stickpea	*Calliandra biflora*	2	1	2	Plant.			Resident
White-faced Ibis	*Plegadis chihi*	0	2	0	Prefers freshwater marshes.		T	Resident
West indian manatee	*Trichechus manatus*	0	3	0	Gulf and bay system; opportunistic, aquatic herbivore	LE	E	Migrant
White-tailed Hawk	*Buteo albicaudatus*	1	2	2	Coastal prairies, savannahs and marshes in Gulf coastal plain		T	Nesting/Migrant
Whooping Crane	*Grus americana*	0	3	0	Potential migrant	LE	E	Migrant
Wood Stork	*Mycteria americana*	0	2	0	Forages in prairie ponds, ditches, and shallow standing water formerly nested in TX		T	Migrant
Zone-tailed Hawk	*Buteo albonotatus*	1	2	2	Arid, open country including deciduous or pine-oak woodland; nests in various habitats and sites		T	Nesting/Migrant

[1] Texas Parks and Wildlife Department (TPWD), Unpublished 2005, March 2005, Data and Map Files of the Wildlife Science Research and Diversity Division maintained by TPWD, Austin, Texas.

- LE/LT=Federally Listed Endangered/Threatened
- E/SA, T/SA=Federally Listed Endangered/Threatened by Similarity of Appearance
- C1=Federal Candidate for Listing
- DL, PDL=Federally Delisted/Proposed for Delisting
- NL=not Federally Listed
- E, T=State Listed Endangered/Threatened
- PE, PT=Federally Proposed Endangered/ Threatened
- Blank = Rare, but no regulatory listing status

One endangered species known to exist near the pipeline corridor is the Attwater's Greater Prairie Chicken, which is found in Goliad and Victoria Counties. The Attwater's Greater Prairie Chicken prefers the coastal prairies grassland in area 0 to 24 inches in vegetation height. Many migratory birds are dependent on the quality of estuarine environments in order to complete the foraging and nesting of their migration. One of the most well known of the migratory birds found in the project area is the Whooping Crane (*Grus Americana)*, which is listed as endangered by both USFWS and TPWD. Two other migratory birds known to the project area are listed as threatened by TPWD: the Reddish Egret (*Egretta rufescens*), and the Piping Plover (*Charadrius melodus*). The Piping Plover is also listed as threatened by USFWS.

A rookery has been identified near the pipeline route in Victoria County, and the threatened Bald Eagle (*Haliaeetus leucoephalus*) nests and uses habitat in Jackson County. The proposed pipeline route extends through about 2 miles of the Bald Eagle habitat. These predatory birds usually inhabit areas near large lakes or rivers.

Big red sage (Salvia penstemonoides), Two-flower Stickpea (Calliandra biflora), Coastal Gay Feather (*Liatris bracteata*), Plains Gumweed (*Grindelia oolepsis*), Elmendorf's Onion (*Allium elmendorfii*), Parks' Jointweed (*Polygonella parksii*), Threeflower Broomweed (*Thurovia triflora*) and Welder Machaeranthera (Psilactis heterocarpa) are all rare plants found in the project corridor. The Two-Flower Stickpea, Coastal Gay-feather and Parks' Jointweed are found within one mile of the proposed pipeline route. These three species are usually found in grassland habitats. The Big Red Sage grows in creek beds and seepage slopes of limestone canyons.

Field surveys conducted at the appropriate phase of development should be employed to minimize the impacts of construction and operation on sensitive resources. Specific project features, such as well field, pipelines, and off-channel reservoirs generally have sufficient design flexibility to avoid most impacts or significantly mitigate potential impacts to geographically limited Environmental and cultural resource sites.

Matagorda Bay is an estuarine environment dependent on freshwater inflows from the Colorado Rivers. Changes in streamflow in the Colorado River below a Bay City diversion were reported during the Project Viability Assessment for the LCRA-SAWS Water Project in November 2004. It was concluded that diversion of previously existing surface water from the Lower Colorado River Basin would not significantly alter the existing freshwater inflow regime of Matagorda Bay, or the existing dissolved oxygen levels in the Colorado River. The results of the environmental studies (water quality, river habitat, and bay health) have not revealed any "show stoppers" for the LSWP although the studies are in their early stages. It is expected that the ongoing studies will identify methods for designing and operating the LSWP to meet environmental needs as determined by legislative requirements, agency guidance, and/or permit conditions[8].

[8] Ibid.

Cultural resources protection on public lands in Texas is afforded by the Antiquities Code of Texas (Title 9, Chapter 191, Texas Natural Resource Code of 1977), the National Historic Preservation Act (Pl96-515), and the Archeological and Historic Preservation Act (PL93-291). Cultural resource occurrences within this project area are expected to be numerous due to the number of stream crossings along the pipeline route, and the known number of significant archaeological sites near Lake Texana, Victoria, and the Colorado River to name a few of the areas included by the project. Considering that the owner or controller of the project will likely be a political subdivision of the State of Texas (i.e. river authority, municipality, county, etc.), they will be required to coordinate with the Texas Historical Commission prior to project construction. If the project will affect waters of the United States or wetlands, the project sponsor will also be required to coordinate with the U.S. Army Corps of Engineers regarding impacts to cultural resources

4C.9.4 Engineering and Costing

As part of their agreement, SAWS and LCRA have prepared a Project Viability Assessment[9] (PVA) that is to be updated annually. The PVA includes five elements: water availability, water quality, impacts to Matagorda Bay, meeting the needs of local agricultural interests, and project cost. In order to be consistent with both the PVA study and the Region L costing procedures (Appendix A), cost estimates for the LSWP, using the Region L costing procedures have been provided by LCRA, SAWS, and their consultants[10]. Adjustments have been added to these costs to account for integration and associated project costs. The major facilities that would need to be constructed to divert, store, and deliver water from the Colorado River near Bay City to the Twin Oaks facility in south Bexar County and associated costs are summarized in Table 4C.9-2.

The diversion facilities for the off-channel storage facility would allow average flows to pass the transmission intake, while withdrawing excess flows for storage. When water is unavailable in the river for delivery, the off-channel storage facility would release water back into the river to be diverted at the downstream transmission intake. Additional information regarding operations of facilities may be found in the PVA.

[9] CH2MHill, "2005 Project Viability Assessment," Lower Colorado River Authority, October 2005
[10] LCRA, Electronic Communication, October 19, 2005

Table 4C.9-2.
Cost Estimate Summary for
LCRA-SAWS Water Project – Bay City to Bexar County
(Second Quarter 2002 Prices)

Item	*Region L Estimated Costs (2nd Quarter 2002 Prices)*
Capital Costs	
Colorado River Diversion Works	$230,476,000
Off-Channel Storage Facilities (1-250,000 acft facility)	$181,504,000
Primary Intake and Transmission Pump Stations (141 MGD)[1]	$39,810,000
Transmission Pipeline (90 in dia., 161 miles)	$384,239,000
Terminal Storage (25,000 acft)[2]	$40,300,000
Water Treatment Plant (141 MGD)[1]	$132,927,000
Integration[2]	$140,748,000
Well Field (59 Wells, 2000 GPM)	$49,961,000
Agriculture Conservation	$89,150,000
Total Capital Cost	**$1,289,115,000**
Engineering, Legal Costs and Contingencies (E, A, L, F, B, & C) [3]	$431,978,000
Environmental & Archaeology Studies and Mitigation	$12,080,000
Study Period Costs[4]	$27,700,000
Land Acquisition and Surveying	$19,979,000
Interest During Construction (4 years)	$288,161,000
Total Project Cost	**$2,069,013,000**
Annual Costs	
Debt Service (6 percent, 30 years)	$124,843,000
Reservoir Debt Service (6 percent, 40 years)	$23,299,000
Operation and Maintenance	
Pipeline and Pump Station[5]	$4,991,000
Dam and Reservoir[6]	$6,018,000
Water Treatment Plant	$12,291,000
Ag Conservation	$2,655,000
Well Field	$500,000
Pumping Energy Costs	$19,563,000
Purchase of Water (25% of 150,000 acft/yr @ $115/acft)	$4,700,000
Total Annual Cost	**$198,860,000**
Available Project Yield (acft/yr)	150,000
Annual Cost of Water ($ per acft)	$1,326
Annual Cost of Water ($ per 1,000 gallons)	$4.07

[1]Regional Planning costs procedure plans for a 5% downtime; the PVA estimates do not account for downtime.
[2]Cost estimate not provided in PVA – Region L cost used with CCI adjustments, where appropriate.
[3]E, A, L, F, B, & C = Engineering, Administration, Legal, Financing, Bonding, & Contingencies
[4]LSWP Study Period Costs in the PVA
[5]O&M for diversion works, wells, & off-channel reservoirs covered by Purchase of Water Cost.
[6]Reservoir O&M for Terminal Storage only. O&M for off-channel reservoirs covered by Purchase of Water Cost.

The 161-mile, 90-inch pipeline, would deliver water from the river at a uniform rate of 141 MGD (150,000 acft/yr with 5 percent downtime for maintenance) to the SAWS Twin Oaks facility, as shown in Figure 4C.9-1. The capital cost for this strategy is $1,289,115,000. With contingencies, land acquisition, interest during construction, engineering, legal costs, and other studies, the total project cost would be $2,069,013,000. Financing the non-reservoir portion of the project over 30 years at a 6 percent annual interest rate results in an annual cost of $124,843,000. Estimated cost for the off-channel reservoirs, financed at 6 percent for 40 years, is $23,299,000 annually. The annual costs, including debt repayment, interest, pumping energy, raw water purchases, and operation and maintenance, total $198,860,000. For an annual supply of 150,000 acft, the resulting annual cost of water of is $1,326 per acft/yr, or $4.07 per 1,000 gallons.

A preliminary estimate of cost for a potential alternative or additional diversion from the Colorado River at Bastrop for development of an 18,000 acft/yr water supply for water user groups in Caldwell and Hays Counties is included as Table 4C.9-3. As indicated in Table 4C.9-3, the total project cost for diversion, off-channel storage, transmission, and treatment facilities is $127,671,000. Annual costs including debt service, operations and maintenance, power, and water purchase total $20,599,000. For delivery of a firm supply of 18,000 acft/yr, the estimated unit cost of this potential project is $1,144/acft/yr.

Table 4C.9-3.
Cost Estimate Summary for
LCRA-SAWS Water Project – Bastrop to Hays County
(Second Quarter 2002 Prices)

Item	Region L Estimated Costs (2nd Quarter 2002 Prices)
Capital Costs	
Off-Channel Storage (10,000 acft)	$21,566,000
Intake and Pump Station	$21,485,000
Transmission Pipeline (30 in dia., 35 miles)	$19,770,000
Transmission Pump Station(s)	$3,675,000
Water Treatment Plant (16 MGD)	$18,106,000
Total Capital Cost	**$84,602,000**
Engineering, Legal Costs and Contingencies	$28,623,000
Environmental & Archaeology Studies and Mitigation	$2,277,000
Land Acquisition and Surveying (651 acres)	$2,692,000
Interest During Construction (2 years)	$9,477,000
Total Project Cost	**$127,671,000**
Annual Costs	
Debt Service (6 percent, 30 years)	$6,781,000
Reservoir Debt Service (6 percent, 40 years)	$2,282,000
Operation and Maintenance	
Intake, Pipeline, Pump Station	$819,000
Dam and Reservoir	$323,000
Water Treatment Plant	$1,536,000
Pumping Energy Costs (97,984,986 kW-hr @ 0.06 $/kW-hr)	$5,879,000
Agriculture & Groundwater Cost (Bastrop)	$900,000
Purchase of Water (18,000 acft/yr @ 115.5 $/acft)	$2,079,000
Total Annual Cost	**$20,599,000**
Available Project Yield (acft/yr)	18,000
Annual Cost of Water ($ per acft)	$1,144
Annual Cost of Water ($ per 1,000 gallons)	$3.51

4C.9.5 Implementation Issues

Institutional arrangements are needed to implement projects, potentially including financing on a regional basis.

Requirements for Purchase and Amendments to Existing Water Rights

1. Obtain TCEQ approval for amendments to the existing water rights to reflect:
   a. New type of water use.
   b. New diversion point.

   c. Interbasin transfer.
2. Water sales contracts must be approved by the TCEQ.

Off-Channel Reservoir

1. Necessary permits for the off-channel storage reservoir could include:
   a. TCEQ Storage permit.
   b. USCE Sections 10 and 404 dredge and fill permits for the reservoir and pipelines.
   c. GLO Sand and Gravel Removal review.
   d. GLO Easement for use of state-owned land.
   e. Coastal Coordination Council review.
   f. TPWD Sand, Gravel, and Marl permit.
2. Permitting may require these studies:
   a. Assessment of changes in instream flow and freshwater inflows to bays and estuaries.
   b. Habitat mitigation plan.
   c. Environmental studies.
   d. Cultural resource studies.
3. Land must be acquired through either negotiations or condemnation.
4. Relocations for the reservoirs could include:
   a. County roads.
   b. Utilities.

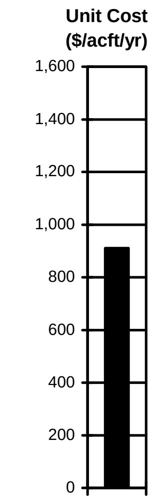
Groundwater Well Field

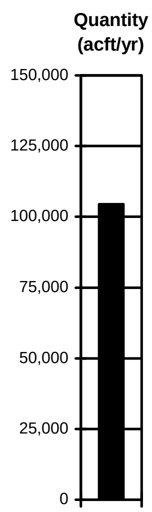
1. Competition for groundwater in the area with others.
2. Potential regulations by local groundwater district(s).
3. Insufficient technical data and information on the hydrogeology and environment to make a comprehensive determination on the effects of pumping the Gulf Coast Aquifer for an extended period of time.

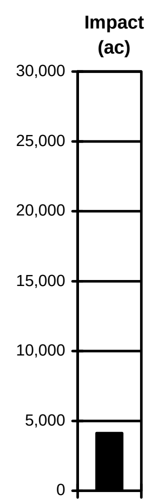
Requirements Specific to the Transmission Pipeline

1. Necessary permits:
   a. USCE Sections 10 and 404 dredge and fill permits for stream crossings.
   b. GLO Sand and Gravel Removal permits.
   c. TPWD Sand, Gravel and Marl permit for river crossings.
2. Right-of-way and easement acquisition.
3. Crossings:
   a. Highways and railroads.
   b. Creeks and rivers.
   c. Other utilities.

2006 South Central Texas Regional Water Plan
Water Management Strategy Summary Sheet







Name: Lower Guadalupe Water Supply Project – In-basin Use with Shared Facilities (LSWP)

Description: This water management strategy examines the potential cost savings associated with shared transmission, treatment, and integration/distribution facilities for the Lower Guadalupe Water Supply Project (LGWSP) and the LCRA-SAWS Water Project (LSWP). Assuming integrated concurrent or phased development of these two projects is feasible, shared facilities could include a 114-inch 70-mile segment of the transmission pipeline from Goliad County to a terminal storage site in southeastern Bexar County, 2 transmission pump stations, and a new or expanded water treatment plant at the Twin Oaks property in south Bexar County.

***Decade Needed*:** 2010 – 2020

Cost, Quantity of Water, and Land Impacted

Unit Cost of Water:	**$911**	**$/acft/yr**	**Treated Water Delivered**
Quantity of Water:	**104,471**	**acft/yr**	**Reliability = Firm**
Land Impacted:	**4,123**	**acres**	

Additional Considerations per Regional Water Planning Guidelines

Environmental Factors:

Wintering population of endangered Whooping Cranes at the Aransas National Wildlife Refuge located adjacent to lower San Antonio Bay. Pipeline could traverse Attwater Prairie Chicken habitat. Surface water diversions from an Ecologically Significant River & Stream Segment per TPWD.

Impacts on Water Resources:

Some reductions in freshwater inflows to the Guadalupe Estuary associated with greater utilization of existing water rights and new appropriation of streamflow. Modest long-term reductions in aquifer levels with more significant transient reductions during severe drought.

Impacts on Agricultural & Natural Resources:

Minimal, if any.

Other Relevant Factors per SCTRWPG:

Encourages beneficial use of available rights. Protects instream flows and recreational opportunities through lower basin diversion. Conformance with groundwater conservation district rules. Interactions and cumulative effects of Region L and Region N water management strategies including potential exports of groundwater from Refugio and surrounding counties. Simultaneous implementation of LGWSP and LSWP could have significant impact on water rates and bonded indebtedness. Projects currently planned for implementation at different times.

Comparison of Strategies to Meet Needs:

Moderate unit cost. No conflicts with other recommended water management strategies.

Interbasin Transfer Issues:

TWDB and/or Legislative clarification of the interbasin transfer status of this project is necessary.

Third-Party Impacts of Voluntary Transfers:

None Anticipated.

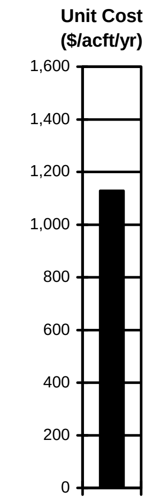
Regional Efficiency:

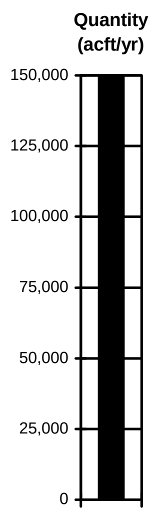
Based on pro-ration of costs by quantity of water delivered, shared transmission and treatment facilities provides economy of scale resulting in potential reductions in project cost of $122,123,000 and in unit cost of $122/acft/yr (11.8%) for the LGWSP.

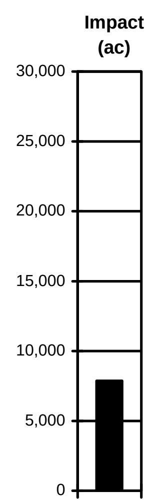
Water Quality Considerations:

Bromides in groundwater mixed with surface water may increase treatment costs in order to meet disinfection by-product requirements in the treated-chlorinated finished water.

2006 South Central Texas Regional Water Plan
Water Management Strategy Summary Sheet







Name: **LCRA-SAWS Water Project (LSWP)** ***with Shared Facilities (LGWSP)***

Description: This water management strategy examines the potential cost savings associated with shared transmission, treatment, and integration/distribution facilities for the LCRA-SAWS Water Project (LSWP) and the Lower Guadalupe Water Supply Project (LGWSP). Assuming integrated concurrent or phased development of these two projects is feasible, shared facilities could include a 114-inch 70-mile segment of the transmission pipeline from Goliad County to a terminal storage site in southeastern Bexar County, 2 transmission pump stations, and a new or expanded water treatment plant at the Twin Oaks property in south Bexar County.

***Decade Needed*:** 2010 – 2020

Cost, Quantity of Water, and Land Impacted

Unit Cost of Water:	**$1,128**	**$/acft/yr**	**Treated Water Delivered**
Quantity of Water:	**150,000**	**acft/yr**	**Reliability = Firm**
Land Impacted:	**7,873**	**acres**	

Additional Considerations per Regional Water Planning Guidelines

Environmental Factors:

Potential concerns with endangered species, habitat, cultural resources, and TPWD Ecologically Unique Stream Segments. Endangered species include the Attwater's Prairie Chicken, Eskimo Curlew, Jaguarundi, & Ocelot. Pipeline could come in close proximity to a Bald Eagle rookery in Jackson County.

Impacts on Water Resources:

Reductions in freshwater inflows to Matagorda Bay associated with greater utilization of existing water rights. Potential effects of these reductions are being studied by LCRA & SAWS.

Impacts on Agricultural & Natural Resources:

There are potential increases in reliable water supply for irrigation and improved irrigation efficiency in Region K. Off-channel reservoirs will inundate approximately 6,750 acres in Matagorda County.

Other Relevant Factors per SCTRWPG:

Encourages beneficial use of available rights. Protects instream flows and recreational opportunities through lower basin diversion. Equitable cost sharing for development of water supplies in Region K and Region L. Simultaneous implementation of LSWP and LGWSP could have significant impact on water rates and bonded indebtedness. Projects currently planned for implementation at different times.

Comparison of Strategies to Meet Needs:

Moderate to high unit cost. No conflicts with other recommended water management strategies.

Interbasin Transfer Issues:

An amendment to the existing LCRA permits for the interbasin transfer of this water would be required. Environmental flow constraints limiting diversions under the existing water rights may be added during the amendment process.

Third-Party Impacts of Voluntary Transfers:

Potential benefits to Lower Colorado River Basin irrigation interests in Region K.

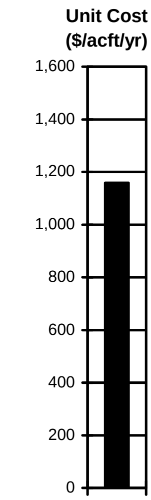
Regional Efficiency:

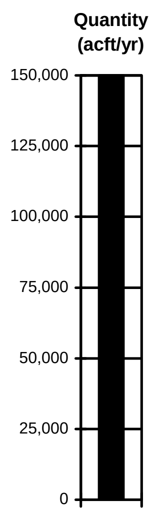
Based on pro-ration of costs by quantity of water delivered, shared transmission and treatment facilities provides economy of scale resulting in potential reductions in project cost of $90,472,000 and in unit cost of $59/acft/yr (5.0%) for the LSWP.

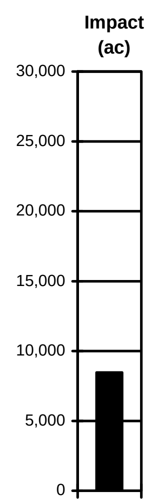
Water Quality Considerations:

None of significant concern.

2006 South Central Texas Regional Water Plan
Water Management Strategy Summary Sheet







Name: **LCRA-SAWS Water Project (LSWP) with Shared Facilities (Garwood)**

Description: This water management strategy examines the potential cost savings associated with shared transmission facilities for the LCRA-SAWS Water Project (LSWP) with the City of Corpus Christi's Garwood Project. Assuming integrated concurrent or phased development of these two projects is feasible, shared facilities could include a 90-inch 37-mile segment of the transmission pipeline from Matagorda County to the pump station at Lake Texana, an intake, and pump station.

***Decade Needed*:** 2010 – 2020

Cost, Quantity of Water, and Land Impacted

Unit Cost of Water:	**$1,159**	**$/acft/yr**	**Treated Water Delivered**
Quantity of Water:	**150,000**	**acft/yr**	**Reliability = Firm**
Land Impacted:	**8,468**	**acres**	

Additional Considerations per Regional Water Planning Guidelines

Environmental Factors:

Potential concerns with endangered species, habitat, cultural resources, and TPWD Ecologically Unique Stream Segments. Endangered species include the Attwater's Prairie Chicken, Eskimo Curlew, Jaguarundi, & Ocelot. Pipeline could come in close proximity to a Bald Eagle rookery in Jackson County.

Impacts on Water Resources:

Reductions in freshwater inflows to Matagorda Bay associated with greater utilization of existing water rights. Potential effects of these reductions are being studied by LCRA & SAWS.

Impacts on Agricultural & Natural Resources:

There are potential increases in reliable water supply for irrigation and improved irrigation efficiency in Region K. Off-channel reservoirs will inundate approximately 6,750 acres in Matagorda County.

Other Relevant Factors per SCTRWPG:

Encourages beneficial use of available rights. Protects instream flows and recreational opportunities through lower basin diversion. Equitable cost sharing for development of water supplies in Region K and Region L. Projects currently planned for implementation at different times.

Comparison of Strategies to Meet Needs:

Moderate to high unit cost. No conflicts with other recommended water management strategies.

Interbasin Transfer Issues:

An amendment to the existing LCRA permits for the interbasin transfer of this water would be required. Environmental flow constraints limiting diversions under the existing water rights may be added during the amendment process.

Third-Party Impacts of Voluntary Transfers:

Potential benefits to Lower Colorado River Basin irrigation interests in Region K.

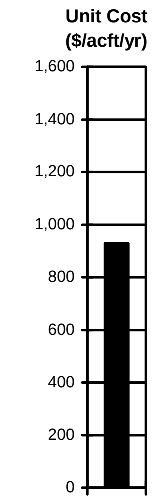
Regional Efficiency:

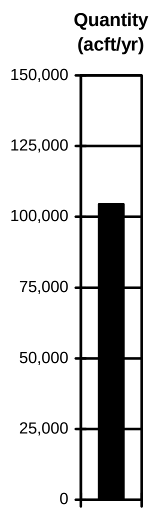
Based on pro-ration of costs by quantity of water delivered, shared transmission and treatment facilities provides economy of scale resulting in potential reductions in project cost of $100,768,000 and in unit cost of $28/acft/yr (2.4%) for the LSWP.

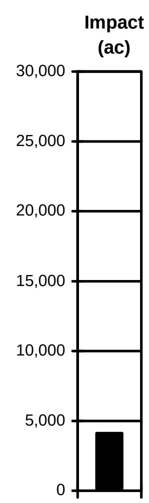
Water Quality Considerations:

None of significant concern.

2006 South Central Texas Regional Water Plan
Water Management Strategy Summary Sheet







Name:* *Lower Guadalupe Water Supply Project with Shared Facilities (LSWP & Garwood)

Description: This water management strategy examines the potential cost savings associated with shared transmission, treatment, and integration/distribution facilities for the LCRA-SAWS Water Project (LSWP) and Lower Guadalupe Water Supply Project (LGWSP) and shared transmission facilities with the Corpus Christi Garwood Project. Assuming integrated concurrent or phased development of these three projects is feasible, shared facilities could include a 90-inch 37-mile segment of the transmission pipeline, intake, and pump station from Matagorda County to the pump station at Lake Texana, a 114-inch 70-mile segment of the transmission pipeline from Goliad County to a terminal storage site in southeastern Bexar County, 2 transmission pump stations, and a new or expanded water treatment plant at the Twin Oaks property in south Bexar County.

***Decade Needed*:** 2010 – 2020

Cost, Quantity of Water, and Land Impacted

Unit Cost of Water:	**$929**	**$/acft/yr**	**Treated Water Delivered**
Quantity of Water:	**104,471**	**acft/yr**	**Reliability = Firm**
Land Impacted:	**4,123**	**acres**	

Additional Considerations per Regional Water Planning Guidelines

Environmental Factors:
Wintering population of endangered Whooping Cranes at the Aransas National Wildlife Refuge located adjacent to lower San Antonio Bay. Pipeline could traverse Attwater Prairie Chicken habitat. Surface water diversions from an Ecologically Significant River & Stream Segment per TPWD.

Impacts on Water Resources:
Some reductions in freshwater inflows to the Guadalupe Estuary associated with greater utilization of existing water rights and new appropriation of streamflow. Modest long-term reductions in aquifer levels with more significant transient reductions during severe drought.

Impacts on Agricultural & Natural Resources:
Minimal, if any.

Other Relevant Factors per SCTRWPG:
Encourages beneficial use of available rights. Protects instream flows and recreational opportunities through lower basin diversion. Conformance with groundwater conservation district rules. Interactions and cumulative effects of Region L and Region N water management strategies including potential exports of groundwater from Refugio and surrounding counties. Simultaneous implementation of LGWSP and LSWP could have significant impact on water rates and bonded indebtedness. Projects currently planned for implementation at different times.

Comparison of Strategies to Meet Needs:
Moderate unit cost. No conflicts with other recommended water management strategies.

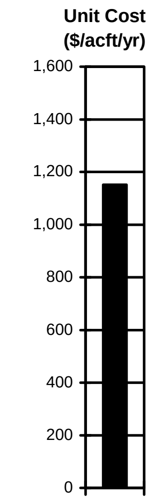
Interbasin Transfer Issues:
TWDB and/or Legislative clarification of the interbasin transfer status of this project is necessary.

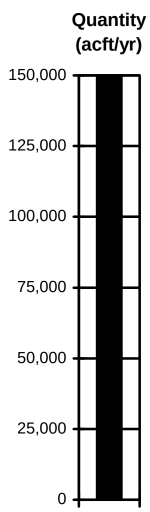
Third-Party Impacts of Voluntary Transfers:
None Anticipated.

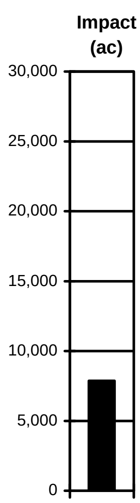
Regional Efficiency:
Based on pro-ration of costs by quantity of water delivered, shared transmission and treatment facilities provides economy of scale resulting in potential reductions in project cost of $118,391,000 and in unit cost of $104/acft/yr (10.1%) for the LGWSP.

Water Quality Considerations:
Bromides in groundwater mixed with surface water may increase treatment costs in order to meet disinfection by-product requirements in the treated-chlorinated finished water.

2006 South Central Texas Regional Water Plan
Water Management Strategy Summary Sheet







Name: **LCRA-SAWS Water Project (LSWP)** ***with Shared Facilities (LGWSP & Garwood)***

Description: This water management strategy examines the potential cost savings associated with shared transmission, treatment, and integration/distribution facilities for the LCRA-SAWS Water Project (LSWP) and Lower Guadalupe Water Supply Project (LGWSP) and shared transmission facilities with the Corpus Christi Garwood Project. Assuming integrated concurrent or phased development of these three projects is feasible, shared facilities could include a 90-inch 37-mile segment of the transmission pipeline, intake, and pump station from Matagorda County to the pump station at Lake Texana, a 114-inch 70-mile segment of the transmission pipeline from Goliad County to a terminal storage site in southeastern Bexar County, 2 transmission pump stations, and a new or expanded water treatment plant at the Twin Oaks property in south Bexar County.

***Decade Needed*:** 2010 – 2020

Cost, Quantity of Water, and Land Impacted

Unit Cost of Water:	**$1,151**	**$/acft/yr**	**Treated Water Delivered**
Quantity of Water:	**150,000**	**acft/yr**	**Reliability = Firm**
Land Impacted:	**7,873**	**acres**	

Additional Considerations per Regional Water Planning Guidelines

Environmental Factors:
Potential concerns with endangered species, habitat, cultural resources, and TPWD Ecologically Unique Stream Segments. Endangered species include the Attwater's Prairie Chicken, Eskimo Curlew, Jaguarundi, & Ocelot. Pipeline could come in close proximity to a Bald Eagle rookery in Jackson County.

Impacts on Water Resources:
Reductions in freshwater inflows to Matagorda Bay associated with greater utilization of existing water rights. Potential effects of these reductions are being studied by LCRA & SAWS.

Impacts on Agricultural & Natural Resources:
There are potential increases in reliable water supply for irrigation and improved irrigation efficiency in Region K. Off-channel reservoirs will inundate approximately 6,750 acres in Matagorda County.

Other Relevant Factors per SCTRWPG:
Encourages beneficial use of available rights. Protects instream flows and recreational opportunities through lower basin diversion. Equitable cost sharing for development of water supplies in Region K and Region L. Simultaneous implementation of LGWSP and LSWP could have significant impact on water rates and bonded indebtedness. Projects currently planned for implementation at different times.

Comparison of Strategies to Meet Needs:
Moderate to high unit cost. No conflicts with other recommended water management strategies.

Interbasin Transfer Issues:
An amendment to the existing LCRA permits for the interbasin transfer of this water would be required. Environmental flow constraints limiting diversions under the existing water rights may be added during the amendment process.

Third-Party Impacts of Voluntary Transfers:
Potential benefits to Lower Colorado River Basin irrigation interests in Region K.

Regional Efficiency:
Based on pro-ration of costs by quantity of water delivered, shared transmission and treatment facilities provides economy of scale resulting in potential reductions in project cost of $69,458,000 and in unit cost of $36/acft/yr (3.0%) for the LSWP.

Water Quality Considerations:
None of significant concern.

(This page intentionally left blank.)

4C.10 LCRA/SAWS Water Project with Shared Transmission Facilities

4C.10.1 Description of Water Management Strategy

This water management strategy examines the potential cost savings associated with shared transmission, treatment, and integration/distribution facilities for the LCRA-SAWS Water Project (LSWP) with two other stand alone water management strategies – the Lower Guadalupe Water Supply Project (LGWSP) of the South Central Texas Regional Water Plan and the City of Corpus Christi's Garwood Project in the Region N Water Plan. The combining of facilities was analyzed three ways:

1. Shared facilities between LSWP and LGWSP Project (A);
2. Shared facilities between LSWP and City of Corpus Christi's Garwood Project (B); and
3. Shared facilities among LWSP, LGWSP, and City of Corpus Christi's Garwood Project (C).

The potential shared facilities are located in Figure 4C.10-1 in the LSWP. For specific information regarding the individual stand alone projects, see Section 4C.9 for the LCRA-SAWS Water Project (LSWP) and Section 4C.7 for the Lower Guadalupe Water Supply Project (LGWSP) of the South Central Texas Regional Water Plan and Section 4C.14 of the Region N Water Plan for the Corpus Christi Garwood Water Project. Facilities for the LSWP are based on the 2004 Project Viability Assessment.[1]

4C.10.1.1 Shared Facilities Between LCRA-SAWS Water Project (LSWP) & Lower Guadalupe Water Supply Project (LGWSP) (A)

This water management strategy presents estimates of the potential cost savings associated with shared transmission, treatment, and integration/distribution facilities for the LCRA-SAWS Water Project (LSWP) and the Lower Guadalupe Water Supply Project (LGWSP). The shared facilities of the LSWP and LGWSP include a 114-inch 70-mile segment of the transmission pipeline from Goliad County to a terminal storage site in southeastern Bexar County, 2 transmission pump stations, a new or expanded water treatment plant at the Twin Oaks water treatment plant site in south Bexar County, and integration/distribution [Figure 4C.10-1 (A)]. The sharing of facilities between these two strategies assumes integrated concurrent or phased development of these two projects.

[1] CH2MHill, "Project Viability Assessment," Lower Colorado River Authority, November 2004

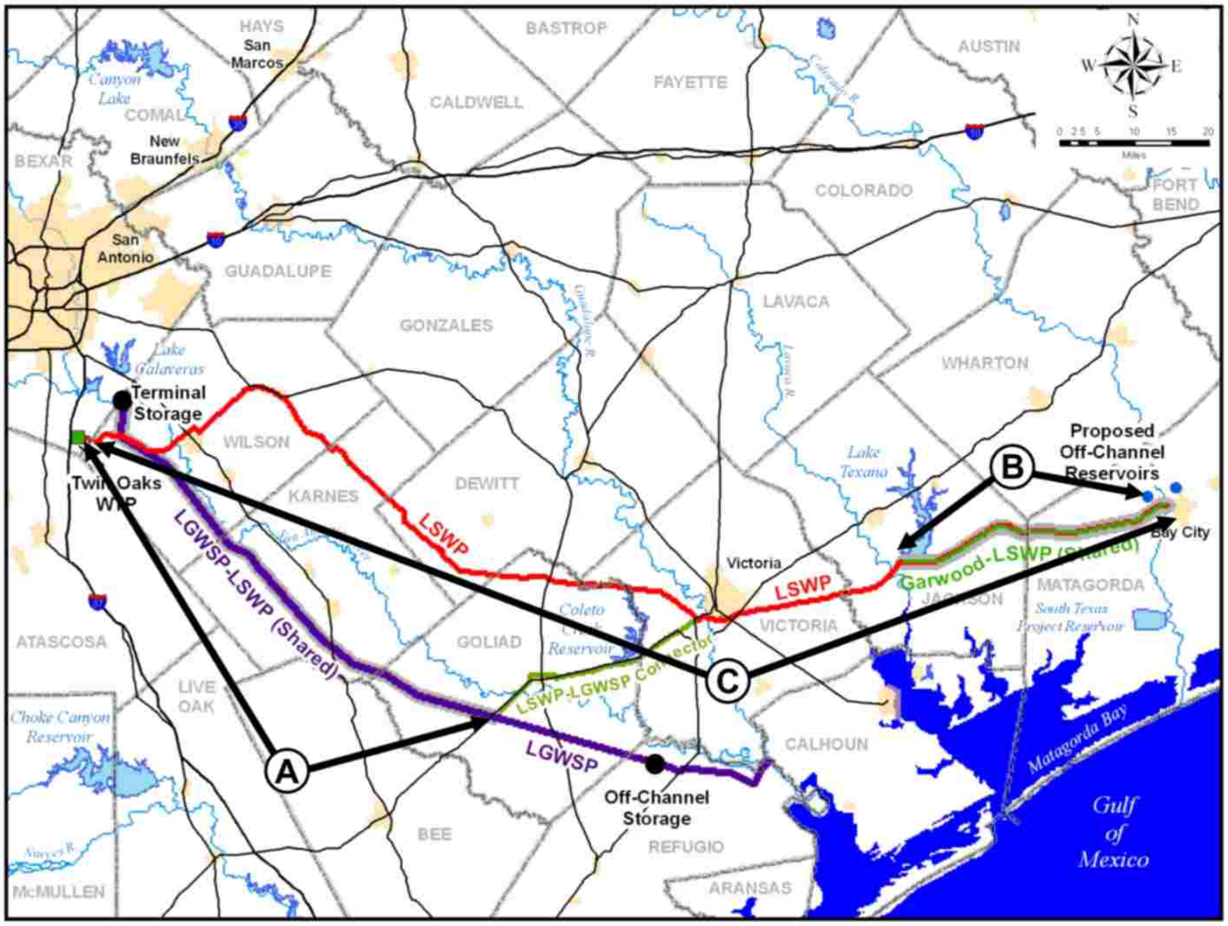


Figure 4C.10-1. Potential Shared Transmission Facilities

4C.10.1.2 Shared Facilities Between LCRA-SAWS Water Project (LSWP) & City of Corpus Christi's Garwood Project (B)

This water management strategy presents estimates of the potential cost savings associated with shared transmission facilities for the LCRA-SAWS Water Project (LSWP) with the City of Corpus Christi's Garwood Project. The shared facilities of the LSWP and the City of Corpus Christi's Garwood Project include a 90-inch 37-mile segment of the transmission pipeline from Matagorda County to the pump station at Lake Texana, an intake, and pump station [Figure 4C.10-1 (B)]. The sharing of facilities between these two strategies assumes integrated concurrent or phased development of these two projects.

4C.10.1.3 Shared Facilities Among LCRA-SAWS Water Project (LSWP), Lower Guadalupe Water Supply Project (LGWSP), & City of Corpus Christi's Garwood Project (C)

This water management strategy examines the potential cost savings associated with shared transmission, treatment, and integration/distribution facilities for the LCRA-SAWS Water Project (LSWP) and Lower Guadalupe Water Supply Project (LGWSP) and shared transmission facilities with the Corpus Christi Garwood Project [Figure 4C.10-1 (C)]. The shared facilities of the LSWP, LGWSP, and City of Corpus Christi's Garwood Project could include a 90-inch 37-mile segment of the transmission pipeline, intake, and pump station from Matagorda County to the pump station at Lake Texana, a 114-inch 70-mile segment of the transmission pipeline from Goliad County to a terminal storage site in southeastern Bexar County, 2 transmission pump stations, and a new or expanded water treatment plant at the Twin Oaks property in south Bexar County. The sharing of facilities between these three strategies assumes integrated concurrent or phased development of these three projects.

4C.10.2 Environmental Issues

The environmental impact of combining facilities of these projects would likely be less compared the overall environmental impact of the stand alone strategies (report sections 4C.7 and 4C.14 referenced above for the environmental issues associated with the stand alone strategies).

4C.10.3 Engineering and Costing

4C.10.3.1 Shared Facilities Between LCRA-SAWS Water Project (LSWP) & Lower Guadalupe Water Supply Project (LGWSP) (A)

Tables 4C.10-1 and 4C.10-2 contain cost estimates for the LSWP and LGWSP, respectively, if shared facilities between the two projects are implemented. The potential cost savings by sharing facilities of the LSWP and LGWSP could total $212,595,000 in project cost: $122,123,000 in savings to the LGWSP and $90,472,000 in savings to the LSWP (Table 4C.10-6). The resulting unit cost savings to the LGWSP and LSWP are $122/acft and $59/acft, respectively (Table 4C.10-6).

4C.10.3.2 Shared Facilities Between LCRA-SAWS Water Project (LSWP) & City of Corpus Christi's Garwood Project (B)

Table 4C.10-3 contains cost estimates for the LSWP if shared facilities between the LSWP and the City of Corpus Christi's Garwood Project are implemented.

The potential cost savings by sharing facilities of the LSWP and LGWSP could total $100,768,000 in project cost to the LSWP (Table 4C.10-6). The resulting unit cost savings to the LSWP are $28/acft (Table 4C.10-6).

Shared Facilities Among LCRA-SAWS Water Project (LSWP), Lower Guadalupe Water Supply Project (LGWSP), & City of Corpus Christi's Garwood Project (C): Tables 4C.10-4 and 4C.10-5 contain cost estimates for the LGWSP and LSWP, respectively, if shared facilities among the three projects are implemented. The potential cost savings by sharing facilities of the LSWP and LGWSP could total $187,849,000 in project cost: $118,391,000 in savings to the LGWSP and $69,458,000 in savings to the LSWP (Table 4C.10-6). The resulting unit cost savings to the LGWSP and LSWP are $104/acft and $36/acft, respectively (Table 4C.10-6).

4C.10.4 Implementation Issues

Implementation of sharing facilities between any of these three strategies is contingent upon the concurrent integration or phased development of projects involved.

Table 4C.10-1.
Cost Estimate Summary for
Lower Guadalupe Water Supply Project with
Inter-Regional Cooperation – LSWP & LGWSP
(Second Quarter 2002 Prices)

Item	***Region L Estimated Costs (2nd Quarter 2002 Prices)***
Capital Costs	
2 Off-Channel Reservoirs (25,000 acft, 1,487 acres each) and Terminal Storage	$82,534,000
Intake and Pump Station (98 MGD)	$37,173,000
Transmission Pipeline (78 in dia., 40 miles; shared 114 in dia., 79 miles)	$235,855,000
Shared Transmission Pump Station(s)	$12,311,000
Well Fields	$40,397,000
Shared Water Treatment Plant (98 MGD)	$68,402,000
Shared Distribution	$85,307,000
Total Capital Cost	**$561,979,000**
Engineering, Legal Costs and Contingencies	$184,900,000
Environmental & Archaeology Studies and Mitigation	$5,976,000
Study Period Costs	$8,771,000
Land Acquisition and Surveying (4,123 acres)	$42,438,000
Interest During Construction (4 years)	$128,748,000
Total Project Cost	**$932,812,000**
Annual Costs	
Debt Service (6 percent, 30 years)	$57,807,000
Reservoir Debt Service (6 percent, 40 years)	$9,112,000
Operation and Maintenance	
Intake, Pipeline, Pump Station, Wells	$5,080,000
Dam and Reservoir	$1,238,000
Water Treatment Plant	$7,514,000
Pumping Energy Costs (169,100,000 kW-hr @ 0.06 $/kW-hr)	$10,146,000
Purchase of Water (70,000 acft/yr @ 60.72 $/acft)	$4,250,000
Total Annual Cost	**$95,147,000**
Available Project Yield (acft/yr)	104,471
Annual Cost of Water ($ per acft)	$911
Annual Cost of Water ($ per 1,000 gallons)	$2.79

Table 4C.10-2.
Cost Estimate Summary for
LCRA-SAWS Water Project with
Inter-Regional Cooperation – LSWP & LGWSP
(Second Quarter 2002 Prices)

Item	***Region L Estimated Costs (2nd Quarter 2002 Prices)***
Colorado River Diversion Works	$96,210,000
2 Off-Channel Reservoirs (75,000 acft, 3,750 acres each) and Terminal Storage	$130,917,000
Primary Intake and Shared Transmission Pump Stations (141 MGD)	$59,858,000
Transmission Pipeline (90 in dia., 113 miles; shared 114 in, 79 miles)	$407,481,000
Well Field (43 Wells, 2000 GPM)	$19,408,000
Shared Water Treatment Plant (141 MGD)	$98,212,000
Shared Distribution	$122,484,000
Agriculture Conservation	$70,632,000
Total Capital Cost	**$1,005,202,000**
Engineering, Legal Costs and Contingencies	$331,447,000
Environmental & Archaeology Studies and Mitigation	$12,742,000
Study Period Costs[1]	$27,872,000
Land Acquisition and Surveying (7,873 acres)	$14,117,000
Interest During Construction (4 years)	$222,621,000
Total Project Cost	**$1,614,001,000**
Annual Costs	
Debt Service (6 percent, 30 years)	$101,654,000
Reservoir Debt Service (6 percent, 40 years)	$14,273,000
Operation and Maintenance	
Intake, Pipeline, Pump Station, Wells	$8,643,000
Dam and Reservoir	$1,964,000
Water Treatment Plant	$10,789,000
Pumping Energy Costs (242,567,000 kW-hr @ 0.06 $/kW-hr)	$14,554,000
Purchase of Water (150,000 acft/yr @ 115.5 $/acft)	$17,325,000
Total Annual Cost	**$169,202,000**
Available Project Yield (acft/yr)	150,000
Annual Cost of Water ($ per acft)	$1,128
Annual Cost of Water ($ per 1,000 gallons)	$3.46

[1]LSWP Study Period Costs in the PVA

Table 4C.10-3.
Cost Estimate Summary for
LCRA-SAWS Water Project with
Inter-Regional Cooperation – LSWP & Garwood
(Second Quarter 2002 Prices)

Item	***Region L Estimated Costs (2nd Quarter 2002 Prices)***
Capital Costs	
Colorado River Diversion Works	$96,210,000
2 Off-Channel Reservoirs (75,000 acft, 3,750 acres each) and Terminal Storage	$130,917,000
Shared Primary Intake and Transmission Pump Stations (141 MGD)	$51,519,000
Transmission Pipeline (Shared 96 in dia., 37 miles; 90 in, 141 miles)	$395,066,000
Well Field (43 Wells, 2000 GPM)	$19,408,000
Water Treatment Plant (141 MGD)	$110,513,000
Distribution	$126,956,000
Agriculture Conservation	$70,632,000
Total Capital Cost	**$1,001,221,000**
Engineering, Legal Costs and Contingencies	$330,674,000
Environmental & Archaeology Studies and Mitigation	$10,859,000
Study Period Costs[1]	$27,872,000
Land Acquisition and Surveying (8,468 acres)	$15,722,000
Interest During Construction (4 years)	$217,357,000
Total Project Cost	**$1,603,705,000**
Annual Costs	
Debt Service (6 percent, 30 years)	$100,444,000
Reservoir Debt Service (6 percent, 40 years)	$14,695,000
Operation and Maintenance	
Intake, Pipeline, Pump Station	$8,888,000
Dam and Reservoir	$1,964,000
Water Treatment Plant	$11,273,000
Pumping Energy Costs (321,667,000 kW-hr @ 0.06 $/kW-hr)	$19,300,000
Purchase of Water (150,000 acft/yr @ 115.5 $/acft)	$17,325,000
Total Annual Cost	**$173,889,000**
Available Project Yield (acft/yr)	150,000
Annual Cost of Water ($ per acft)	$1,159
Annual Cost of Water ($ per 1,000 gallons)	$3.56

[1]LSWP Study Period Costs in the PVA

Table 4C.10-4.
Cost Estimate Summary for
Lower Guadalupe Water Supply Project with
Inter-Regional Cooperation – LSWP, LGWSP, & Garwood
(Second Quarter 2002 Prices)

Item	***Region L Estimated Costs (2nd Quarter 2002 Prices)***
Capital Costs	
2 Off-Channel Reservoirs (25,000 acft, 1,487 acres each) and Terminal Storage	$82,534,000
Intake and Pump Station (98 MGD)	$42,939,000
Transmission Pipeline (78 in dia 37 miles; shared 114 in dia 70 miles)	$235,608,000
Transmission Pump Stations	$1,596,000
Well Fields	$40,397,000
Shared Water Treatment Plant (98 MGD)	$68,402,000
Distribution	$90,821,000
Total Capital Cost	**$562,297,000**
Engineering, Legal Costs and Contingencies	$187,690,000
Environmental & Archaeology Studies and Mitigation	$5,575,000
Study Period Costs	$8,771,000
Land Acquisition and Surveying (4,123 acres)	$41,898,000
Interest During Construction (4 years)	$130,313,000
Total Project Cost	**$936,544,000**
Annual Costs	
Debt Service (6 percent, 30 years)	$58,632,000
Reservoir Debt Service (6 percent, 40 years)	$9,112,000
Operation and Maintenance	
Intake, Pipeline, Pump Station	$5,400,000
Dam and Reservoir	$1,238,000
Water Treatment Plant	$7,514,000
Pumping Energy Costs (181,800,000 kW-hr @ 0.06 $/kW-hr)	$10,908,000
Purchase of Water (70,000 acft/yr @ 60.72 $/acft)	$4,250,000
Total Annual Cost	**$97,054,000**
Available Project Yield (acft/yr)	104,471
Annual Cost of Water ($ per acft)	$929
Annual Cost of Water ($ per 1,000 gallons)	$2.85

Table 4C.10-5.
Cost Estimate Summary for
LCRA-SAWS Water Project with
Inter-Regional Cooperation – LSWP, LGWSP, & Garwood
(Second Quarter 2002 Prices)

Item	***Region L Estimated Costs (2nd Quarter 2002 Prices)***
Capital Costs	
Colorado River Diversion Works	$96,210,000
2 Off-Channel Reservoirs (75,000 acft, 3,750 acres each) and Terminal Storage	$130,917,000
Primary Intake and Shared Transmission Pump Stations (124 MGD)	$63,629,000
Transmission Pipeline (Shared 96 in dia., 37 miles 90 in dia., 76 miles; shared 114 in, 79 miles)	$410,318,000
Well Field (43 Wells, 2000 GPM)	$19,408,000
Shared Water Treatment Plant (141 MGD)	$98,212,000
Shared Distribution	$130,402,000
Agriculture Conservation	$70,632,000
Total Capital Cost	**$1,019,728,000**
Engineering, Legal Costs and Contingencies	$336,389,000
Environmental & Archaeology Studies and Mitigation	$12,166,000
Study Period Costs[1]	$27,872,000
Land Acquisition and Surveying (7,873 acres)	$13,340,000
Interest During Construction (4 years)	$225,520,000
Total Project Cost	**$1,635,015,000**
Annual Costs	
Debt Service (6 percent, 30 years)	$103,180,000
Reservoir Debt Service (6 percent, 40 years)	$14,273,000
Operation and Maintenance	
Intake, Pipeline, Pump Station, Wells	$7,551,000
Dam and Reservoir	$1,964,000
Water Treatment Plant	$10,789,000
Pumping Energy Costs (291,700,000 kW-hr @ 0.06 $/kW-hr)	$17,502,000
Purchase of Water (150,000 acft/yr @ 115.5 $/acft)	$17,325,000
Total Annual Cost	**$172,584,000**
Available Project Yield (acft/yr)	150,000
Annual Cost of Water ($ per acft)	$1,151
Annual Cost of Water ($ per 1,000 gallons)	$3.53

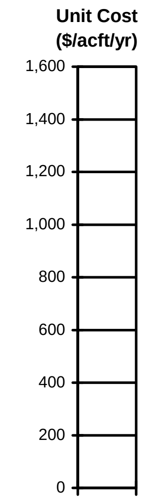
[1]LSWP Study Period Costs in the PVA

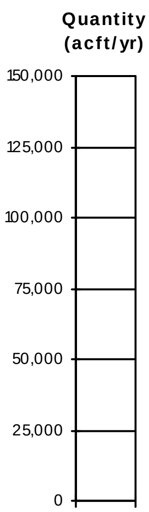
Table 4C.10-6. Cost Estimate Comparison for Shared Facilities Among LCRA-SAWS Water Project (LSWP), Lower Guadalupe Water Supply Project (LGWSP), & City of Corpus Christi's Garwood Project

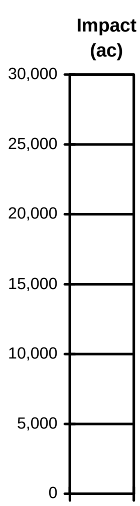
Project	Information Source	Costs	
		Total (Dollars)	Unit ($/acft) (Dollars)
LGWSP Stand Alone	Table 4C.7-3	1,054,935,000	1,033
LGWSP Shared with LSWP	Table 4C.10-1	932,812,000	911
Savings to LGSWP		122,123,000	122
LSWP Stand Alone	Table 4C.9-2	1,704,473,000	1,187
LSWP Shared with LGSWP	Table 4C.10-2	1,614,001,000	1,128
Savings to LSWP		90,472,000	59
LSWP Stand Alone	Table 4C.9-2	1,704,473,000	1,187
LSWP Shared with Corpus Christi Garwood	Table 4C.10-3	1,603,705,000	1,159
Savings to LSWP		100,768,000	28
LGWSP Stand Alone	Table 4C.7-3	1,054,935,000	1,033
LGWSP Shared with LSWP & Corpus Christi Garwood	Table 4C.10-4	936,544,000	929
Savings to LGSWP		118,391,000	104
LSWP Stand Alone	Table 4C.9-2	1,704,473,000	1,187
LSWP Shared with LGSWP & Corpus Christi Garwood	Table 4C.10-5	1,635,015,000	1,151
Savings to LSWP		69,458,000	36

LGWSP is Lower Guadalupe Water Supply Project.
LSWP is Lower Colorado River Authority-San Antonio Water System Water Project.

2006 South Central Texas Regional Water Plan
Water Management Strategy Summary Sheet







Name: Surface Water Rights

Description: The Surface Water Rights water management strategy is included to explicitly recognize that use of water supplies made available under existing water rights by lease or purchase agreements between willing buyers and willing sellers is consistent with the 2006 South Central Texas Regional Water Plan. The addition of diversion points or types and places of use for existing surface water rights is also consistent with the 2006 Regional Water Plan, if necessary authorizations are obtained pursuant to Texas Commission on Environmental Quality (TCEQ) rules and applicable law.

***Decade Needed*:** 2010 – 2060

Cost, Quantity of Water, and Land Impacted

Unit Cost of Water:	**Variable**	**$/acft/yr**	**Raw or Treated Water**
Quantity of Water:	**Variable**	**acft/yr**	**Reliability = Firm**
Land Impacted:	**Variable**	**acres**	

Additional Considerations per Regional Water Planning Guidelines

Environmental Factors:

Limited compared to other strategies because the source of water is existing water rights having prior authorizations for consumptive use. Must consider effects associated with new diversion, storage, transmission, treatment, and/or integration facilities in accordance with applicable state & federal requirements.

Impacts on Water Resources:

"No Injury" rule ensures protection of senior water rights. Potential reductions in instream flows or freshwater inflows to bays & estuaries associated with greater utilization of existing water rights.

Impacts on Agricultural & Natural Resources:

Minimal, if any.

Other Relevant Factors per SCTRWPG:

Encourages beneficial use of available rights. Downstream transfers can protect instream flows and recreational opportunities between the original and amended diversion points.

Comparison of Strategies to Meet Needs:

Low to high unit cost depending on location, reliability, and negotiations between willing buyers and sellers. No conflicts with other recommended water management strategies because existing water rights must be honored in assessment of water availability.

Interbasin Transfer Issues:

Interbasin transfer of water made available under existing surface water rights may involve additional regulatory requirements to amend place of use and may introduce changes in relative priority and inflow passage for environmental flow needs.

Third-Party Impacts of Voluntary Transfers:

None anticipated.

Regional Efficiency:

Maximizes beneficial use of existing permitted resources.

Water Quality Considerations:

None of significant concern.

(This page intentionally left blank.)

4C.11 Surface Water Rights

4C.11.1 Description of Water Management Strategy

The Surface Water Rights water management strategy is included to explicitly recognize that use of water supplies made available under existing water rights by lease or purchase agreements between willing buyers and willing sellers is consistent with the 2006 South Central Texas Regional Water Plan. The addition of diversion points or types and places of use for existing surface water rights is also consistent with the 2006 Regional Water Plan, if necessary authorizations are obtained pursuant to Texas Commission on Environmental Quality (TCEQ) rules and applicable law. It is important to note that this water management strategy is intended to address existing water rights (within currently authorized annual and instantaneous maximum diversion rates) and not applications for new surface water appropriations. Furthermore, this strategy focuses on maximizing beneficial use of existing run-of-river water rights as opposed to the development of new major reservoirs. As described in Section 3.2.1, existing firm supplies from major reservoirs are either committed to current steam-electric power generation uses (Coleto Creek Reservoir and Braunig and Calaveras Lakes) or are the subject of another water management strategy (Canyon Reservoir).

Key applicable water law regarding amendment of existing water rights to facilitate lease/purchase agreements is found in Section 11.122 of the Texas Water Code which requires water rights holders to obtain authorization from TCEQ to *"change the place of use, purpose of use, point of diversion, rate of diversion, acreage to be irrigated, or otherwise alter a water right."* Section 11.122 further provides that *"an amendment, except an amendment to a water right that increases the amount of water authorized to be diverted or the authorized rate of diversion, shall be authorized if the requested change will not cause adverse impact on other water right holders or the environment on the stream of greater magnitude than under circumstances in which the permit, certified filing, or certificate of adjudication that is sought to be amended was fully exercised according to its terms and conditions as they existed before the requested amendment."* This section is identified in the TCEQ rules as the "No Injury" Rule. Pursuant to the "No Injury" Rule, restrictions may be placed upon a right for which amendment is being sought in order to protect senior water rights. An example of such restrictions is subordination of an amended right to water rights situated between the existing and amended diversion locations.

4C.11.2 Available Yield

Available yield of run-of-river surface water rights, whether before or after lease/purchase under the Surface Water Rights water management strategy, is determined using the applicable water availability model (WAM). The Guadalupe – San Antonio River Basin WAM[1] and the Nueces River Basin WAM[2] are the primary tools applicable for consideration of water rights in the South Central Texas Regional Water Planning Area (Region L). These WAMs perform the complex calculations accounting for relative seniority, authorized annual diversion, type(s) of use, maximum diversion rate, instream flow requirements, physical location, and authorized storage associated with a particular water right, in the context of historical hydrology, as necessary to quantify firm diversion or available yield subject to drought of record conditions. Information regarding current surface water rights in Region L is summarized in Appendix B of Volume I.

The following subsections summarize examples of water rights acquisitions and/or planned activities relevant to the Surface Water Rights water management strategy by wholesale water providers and water user groups within Region L. The SCTRWPG intends for these examples to be illustrative of activities consistent with the Surface Water Rights water management strategy and explicitly does not intend to limit recommended activities to those listed herein. With respect to the development of new municipal and industrial water supplies through the Surface Water Rights water management strategy, the SCTRWPG concurs with the TCEQ and the Texas Water Development Board (TWDB) in stressing that such additional supplies should be reliable subject to drought of record conditions. Hence, to the extent that run-of-river water rights intended to be used for new municipal and industrial supplies are not reliable under drought conditions, additional facilities (e.g., off-channel storage) and/or additional sources of supply (e.g., groundwater) must be specified and the overall water management strategy evaluated in accordance with TWDB regional water planning guidelines to ensure consistency with the Regional Water Plan.

[1] HDR Engineering, Inc., "Water Availability in the Guadalupe – San Antonio River Basin," Texas Natural Resource Conservation Commission, December 1999.
[2] HDR Engineering, Inc., "Water Availability in the Nueces River Basin," Texas Natural Resource Conservation Commission, October 1999.

4C.11.2.1 San Antonio Water System (SAWS)

The San Antonio Water System (SAWS) has acquired five surface water rights having a combined total authorized annual diversion of 9,376 acft/yr from the San Antonio River and its tributaries the Medina River and Leon Creek (Table 4C.11-1). These water rights could be used at existing locations or consolidated at downstream location(s) for municipal, industrial, and/or steam-electric uses. At the appropriate time, SAWS may seek authorizations from TCEQ for changes in point(s) of diversion and purpose(s) and place(s) of use for these water rights. Examples of potential uses of these water rights include:

- Diversion from the Medina or San Antonio River in Bexar County for treatment and use by SAWS municipal and industrial customers. Storage authorizations associated with two of the water rights increase reliability under drought conditions.
- Diversion from the San Antonio River near Elmendorf to augment water supplies for steam-electric power generation by the City Public Service Board of San Antonio at their facilities located on Braunig and Calaveras Lakes.
- Diversion from the small reservoir formed by the Guadalupe River Saltwater Barrier and Diversion Dam located immediately downstream of the confluence of the San Antonio and Guadalupe Rivers as an additional source of supply for the Lower Guadalupe Water Supply Project (LGWSP). Pursuant to a May 10, 2001 Water Supply and Delivery Agreement, SAWS is presently a partner in the development of the LGWSP which could provide municipal and industrial water supplies for Bexar County and others.

Future acquisitions of existing water rights, as well as the above and/or other similar uses of existing surface water rights, in accordance with the Surface Water Rights water management strategy, are consistent with the 2006 South Central Texas Regional Water Plan.

Table 4C.11-1.
Example Water Rights Acquisitions by SAWS

Water Right Number	*Priority Date*	*Authorized Storage (acft)*	*Authorized Annual Diversion (acft)*	*Authorized Use*	*Maximum Diversion Rate (cfs)*	*Watercourse*
19-2156	3/24/1926	0	294	Irr	7.80	Medina River
19-2159	3/24/1926	0	60	Irr	2.23	San Antonio River
19-3867	6/22/1981	0	22	Irr	8.00	Medina River
19-5469	5/11/1981	400	1,500	Irr, Ind	30.00	Leon Creek
19-5517	1/30/1995	1,000	7,500	Irr, Ind	50.00	Leon Creek
Total	---	1,400	9,376	---	98.03	---

4C.11.2.2 Bexar Metropolitan Water District (BMWD)

Bexar Metropolitan Water District (BMWD) has acquired four surface water rights having a combined total authorized annual diversion of 7,881 acft/yr from the San Antonio River and its tributaries (Table 4C.11-2). These water rights may be used at existing locations or consolidated at downstream location(s) for municipal uses. At the appropriate time, BMWD may seek authorizations from TCEQ for changes in point(s) of diversion and purpose(s) and place(s) of use for these water rights. One example of potential use of these water rights is diversion from the Medina or San Antonio River in Bexar County for treatment and use by BMWD municipal customers. Storage authorizations associated with three of the water rights increase reliability under drought conditions. Future acquisitions of existing water rights, as well as the above and/or other similar uses of existing surface water rights, in accordance with the Surface Water Rights water management strategy, are consistent with the 2006 South Central Texas Regional Water Plan.

Table 4C.11-2.
Example Water Rights Acquisitions by BMWD

Water Right Number	Priority Date	Authorized Storage (acft)	Authorized Annual Diversion (acft)	Authorized Use	Maximum Diversion Rate (cfs)	Watercourse
19-1959	6/26/1914	0	150	Mun	2.22	San Antonio River
19-1966	8/9/1911	34	481	Mun	2.67	San Antonio River
19-4768	Various	595	5,000	Mun	19.16	Medio Creek & Medina River
19-5549	3/15/1996	148	2,250	Mun	22.30	Polecat & Potranco Creeks
Total	---	777	7,881	---	46.35	---

4C.11.2.3 Canyon Regional Water Authority (CRWA)

Canyon Regional Water Authority (CRWA) has acquired or leased several surface water rights including Certificate of Adjudication No. (CA#) 18-3834 for diversion of 18.52 acft/yr from the Guadalupe River at Lake Dunlap and CA# 19-1155 for diversion of 42 acft/yr from Cibolo Creek. CA# 18-3834 is presently being used by CRWA for municipal supply and is the basic water right for which an amendment seeking additional authorized diversions may be filed with TCEQ as a part of the CRWA Dunlap Project (Section 4C.24). CA# 19-1155 is the basic water right for which an amendment seeking additional authorized diversions may be filed with TCEQ as a part of the CRWA Siesta Project (Section 4C.25). The CRWA Siesta Project is expected to include acquisitions of additional existing water rights, conversion of purpose of use from irrigation to municipal, and consolidation of diversion points to one location on Cibolo Creek. Future acquisitions of existing water rights, as well as the above and/or other similar uses of existing surface water rights, in accordance with the Surface Water Rights water management strategy, are consistent with the 2006 South Central Texas Regional Water Plan. New appropriations or water rights amendments seeking additional diversions as parts of the CRWA Dunlap and Siesta Projects are separate matters.

4C.11.2.4 San Antonio River Authority (SARA)

The San Antonio River Authority (SARA) is considering the acquisition of existing surface water rights from the San Antonio River and its tributaries such as Cibolo Creek. These water rights could be used at existing locations or consolidated at downstream location(s) for municipal or industrial uses. At the appropriate time, SARA may seek authorizations from TCEQ for changes in point(s) of diversion and purpose(s) and place(s) of use for acquired water rights. Examples of potential uses of these water rights include:

- Diversion from Cibolo Creek (and/or its tributaries) or the San Antonio River for treatment and use by potential SARA municipal and industrial customers.
- Diversion from the small reservoir formed by the Guadalupe River Saltwater Barrier and Diversion Dam located immediately downstream of the confluence of the San Antonio and Guadalupe Rivers as an additional source of supply for the Lower Guadalupe Water Supply Project (LGWSP). Pursuant to a May 10, 2001 Water Supply and Delivery Agreement, SARA is presently a partner in the development of the LGWSP which could provide municipal and industrial water supplies for Bexar County and others.

Future acquisitions of existing water rights, as well as the above and/or other similar uses of existing surface water rights, in accordance with the Surface Water Rights water management strategy, are consistent with the 2006 South Central Texas Regional Water Plan.

4C.11.2.5 City of San Marcos

The City of San Marcos is considering the acquisition of existing surface water rights from the San Marcos River with the intent of augmenting future dependable water supplies by

2,867 acft/yr in order to meet projected needs. Examples of potential uses of existing water rights provided by San Marcos include:

- Senior water rights acquisition with relocation of diversion point.
- Junior water rights acquisition and new appropriation with off-channel storage.
- Purchase or lease surplus water under existing water right(s).

At the appropriate time, San Marcos may seek authorizations from TCEQ for changes in point(s) of diversion and purpose(s) and place(s) of use for any acquired water rights. Future acquisitions of existing water rights, as well as the above and/or other similar uses of existing surface water rights, in accordance with the Surface Water Rights water management strategy, are consistent with the 2006 South Central Texas Regional Water Plan.

4C.11.2.6 City of Victoria

The City of Victoria has acquired CA# 18-3860 which authorizes diversion of 260 acft/yr from the Guadalupe River. Victoria is presently involved in the administrative process of obtaining TCEQ authorization to include municipal supply as an authorized purpose of use for the full water right and to change the point of diversion to coincide with Victoria's existing surface water diversion works. Victoria is also considering other opportunities for purchase or lease of additional surface water rights. Future acquisitions of existing water rights, as well as the above and/or other similar uses of existing surface water rights, in accordance with the Surface Water Rights water management strategy, are consistent with the 2006 South Central Texas Regional Water Plan.

4C.11.2.7 City of Kenedy

The City of Kenedy has identified acquisition of existing surface water rights from the San Antonio River and/or its tributaries as an alternative water management strategy to augment future dependable water supplies and meet projected water needs. These water rights could be diverted at existing locations or consolidated at one diversion location for treatment and municipal or industrial uses. At the appropriate time, Kenedy may seek authorizations from TCEQ for changes in point(s) of diversion and purpose(s) and place(s) of use for acquired water rights. Future acquisitions of existing water rights, in accordance with the Surface Water Rights water management strategy, are consistent with the 2006 South Central Texas Regional Water Plan.

4C.11.3 Environmental Issues

Potential environmental issues associated with implementation of the Surface Water Rights water management strategy are somewhat limited compared to other strategies because the source of water is existing water rights having prior authorizations for consumptive use. If an amendment to an existing water right is necessary to implement the strategy, Section 11.122 of the Texas Water Code indicates that only adverse impacts on the environment on the stream of greater magnitude than under circumstances in which the right sought to be amended was fully exercised prior to the amendment need be addressed. Environmental effects associated with new diversion, storage, transmission, treatment, and/or integration facilities necessary to use water available under existing rights must be addressed in accordance with applicable state and federal requirements.

4C.11.4 Engineering and Costing

Estimated costs for purchase or lease of existing surface water rights are highly variable depending upon location, reliability, and negotiations between willing buyers and sellers. Although future acquisitions of specific water rights are not addressed herein, example estimated unit costs might range from a low of about $60/acft/yr for raw water only, pursuant to the LGWSP Water Supply and Delivery Agreement among the Guadalupe-Blanco River Authority (GBRA), SAWS, and SARA, to a composite value of $2,792/acft/yr for several potential projects including appurtenant facilities as identified by the City of San Marcos.

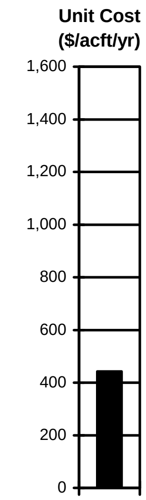
4C.11.5 Implementation Issues

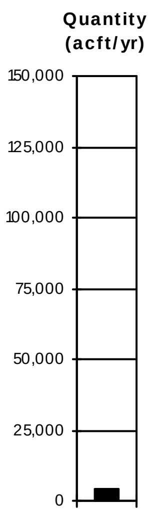
Potentially significant implementation issues associated with the Surface Water Rights water management strategy include the following:

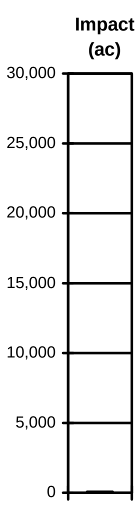
- Quantification and consideration of any potential effects on other water rights, streamflows, and freshwater inflows to bays and estuaries to the extent required by TCEQ rules and applicable state and federal law.
- Changes in the point of diversion may necessitate subordination of an amended right to water rights situated between the existing and amended diversion locations.
- Interbasin transfer of water made available under existing surface water rights may involve additional regulatory requirements to amend place of use and may introduce changes in relative priority and inflow passage for environmental flow needs.
- Run-of-river water rights often require storage and/or groundwater to firm up supply for municipal water use.

(This page intentionally left blank.)

2006 South Central Texas Regional Water Plan
Water Management Strategy Summary Sheet







Name: **Local Groundwater - Carrizo-Wilcox Aquifer**

Description: Additional Carrizo-Wilcox wells and associated facilities to meet needs identified in Regional Plan, as well as treatment costs associated with chlorination and Iron and Manganese removal. Facilities vary with individual water provider. Assumption is made that new wells will connect directly into distribution system, and any piping needed to accomplish this will be accommodated in the 35% contingency costs included in cost estimates; therefore, no pipeline costs are included in estimates.

***Decade Needed*:** 2010 – 2060

Cost, Quantity of Water, and Land Impacted

Unit Cost of Water:	**114 - 443**	**$/acft/yr**	**Treated Water Delivered**
Quantity of Water:	**536- 4,480**	**acft/yr**	**Reliability = Firm**
Land Impacted:	**minimal**	**acres**	

Additional Considerations per Regional Water Planning Guidelines

Environmental Factors: Minimal. Pipelines may traverse endangered or threatened species habitat. Groundwater pumpage could affect spring flows and stream flows in outcrop.

Impacts on Water Resources: Minimal, if any.

Impacts on Agricultural & Natural Resources: Not applicable.

Other Relevant Factors per SCTRWPG: Strategy is extension of methods in existence, and is based upon local experience to meet projected needs. Potential interactions between Bexar Met and SAWS facilities in south Bexar County.

Comparison of Strategies to Meet Needs: Low to Moderate Unit Costs in comparison to recommended strategies for other municipal users.

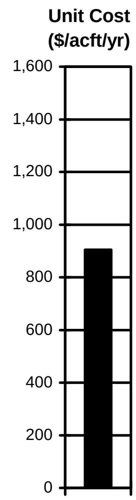
Interbasin Transfer Issues: Not applicable.

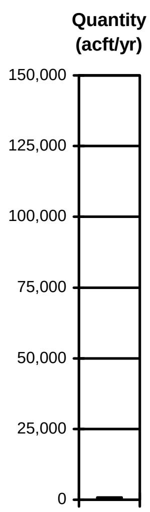
Third-Party Impacts of Voluntary Transfers: Not applicable.

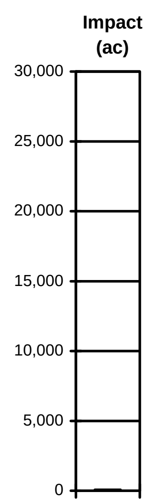
Regional Efficiency: Through use of locally available sources, water needs are met at least cost, in comparison to costs of recommended strategies to meet needs of large urban communities of the region.

Water Quality Considerations: Carrizo-Wilcox water may contain high iron and manganese concentrations.

2006 South Central Texas Regional Water Plan
Water Management Strategy Summary Sheet







Name: **Local Groundwater – Gulf Coast Aquifer**

Description: The City of Kenedy, in Karnes County is expected to need two new supply wells in the Gulf Coast Aquifer added to their system by the year 2060. The facilities include additional Gulf Coast Aquifer wells to meet needs identified in Regional Plan, as well as reverse osmosis membrane system treatment costs associated with TDS removal. Assumption is made that new wells will connect directly into distribution system, and any piping needed to accomplish this will be accommodated in the 35% contingency costs included in cost estimates; therefore, no pipeline costs are included in estimates.

***Decade Needed*:** 2010 – 2060

Cost, Quantity of Water, and Land Impacted

Unit Cost of Water:	**904**	**$/acft/yr**	**Treated Water Delivered**
Quantity of Water:	**780**	**acft/yr**	**Reliability = Firm**
Land Impacted:	**minimal**	**acres**	

Additional Considerations per
Regional Water Planning Guidelines

Environmental Factors: Minimal. Pipeline may traverse endangered or threatened species habitat. Groundwater pumpage could affect spring flows and stream flows in outcrop.

Impacts on Water Resources: Minimal, if any.

Impacts on Agricultural & Natural Resources: Not applicable.

Other Relevant Factors per SCTRWPG: Strategy is extension of methods in existence, and is based upon local experience to meet projected needs.

Comparison of Strategies to Meet Needs: Moderate unit cost, due to need for TDS removal treatment.

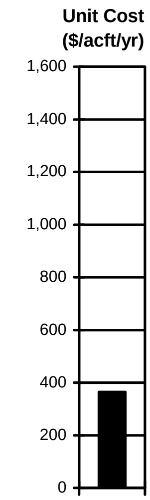
Interbasin Transfer Issues: Not applicable.

Third-Party Impacts of Voluntary Transfers: Not applicable.

Regional Efficiency: Through use of locally available sources, water needs are met from nearby locations, and in this case using poorer quality water than is the case for other recommended strategies of the plan.

Water Quality Considerations: Gulf Coast Aquifer water in this area may contain high TDS concentrations requiring membrane treatment.

2006 South Central Texas Regional Water Plan
Water Management Strategy Summary Sheet



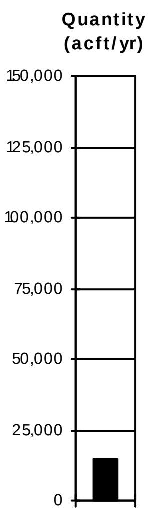
Name: **Local Groundwater - Trinity Aquifer**

Description: Additional Trinity Aquifer wells and associated facilities to meet needs identified in Regional Plan, as well as treatment costs associated with chlorination. Facilities vary with individual water provider. Assumption is made that new wells will connect directly into distribution system, and any piping needed to accomplish this will be accommodated in the 35% contingency costs included in cost estimates; therefore, no conveyance pipeline costs are included in estimates.

***Decade Needed*:** 2010 – 2060

Cost, Quantity of Water, and Land Impacted

Unit Cost of Water:	**329-365**	**$/acft/yr**	**Treated Water Delivered**
Quantity of Water:	**400-15,000**	**acft/yr**	**Reliability = Firm**
Land Impacted:	**Varies (low)**	**acres**	



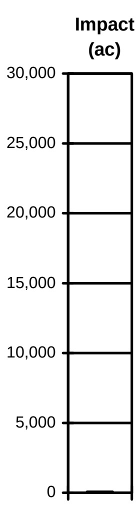
Additional Considerations per
Regional Water Planning Guidelines

Environmental Factors: Minimal. Pipeline may traverse endangered or threatened species habitat. Groundwater pumpage could affect spring flows and stream flows in outcrop.

Impacts on Water Resources: Minimal, if any.

Impacts on Agricultural & Natural Resources: Not applicable.

Other Relevant Factors per SCTRWPG: Groundwater availability modeling was not performed to estimate long-term drawdown associated with these projects. The fault-block geology of the Trinity Aquifer in these areas results in highly variable well yields. Cost estimates are based on average well capacities reported by representatives of water users. Further hydrogeologic studies will be necessary to determine if the reported average well yields used for costing purposes are sustainable over the long term planning period. Additionally, Trinity wells from very deep strata may require treatment for reduction of TDS.



Comparison of Strategies to Meet Needs: Low Unit Cost, in comparison to recommended strategies to meet other municipal needs.

Interbasin Transfer Issues: Not applicable.

Third-Party Impacts of Voluntary Transfers: Not applicable.

Regional Efficiency: Through use of locally available sources, water needs are met at least cost, in comparison to costs of recommended strategies to meet needs of large urban communities of the region.

Water Quality Considerations: Possibly high TDS from very deep strata.

(This page intentionally left blank.)

4C.12 Local Groundwater Supplies

Municipal water systems in the upper Coastal Plains area of the South Central Texas Water Planning Region commonly use the Carrizo-Wilcox, Gulf Coast, or Trinity Aquifers for their supply. These sources may be a strong preference because the water is usually readily available, inexpensive, and often suitable for public water supplies with minimal treatment.

The purposes of this analysis are to:

- Evaluate aquifers and existing well field(s) of each municipality for their ability to meet projected water supply requirements through 2060 based on groundwater supply estimates that are based on reported well capacity for municipalities or WSC's TECQ water system data sheets.
- If additional supplies are needed, identify whether or not additional wells are the most likely water management strategy or whether an alternative strategy, such as purchase from a wholesale water provider, is recommended.
- If additional wells are needed, identify a reconnaissance-level location for new well(s).
- If the water needs to be treated, estimate the cost of the facilities.

The evaluation of individual municipal water systems is at a reconnaissance level and includes the following:

1. Compiled information prepared for the South Central Texas Regional Water Planning Group on current and TWDB's projected populations and water demands for each of the municipalities.
2. Estimated the TCEQ system capacity through 2060 for each water system.
3. Compiled and summarized publicly available information for each municipal water system from TCEQ and TWDB.
4. If the estimated groundwater supply after adjustments was greater than the estimated required capacity in 2060, the evaluation concludes that the existing water supply is adequate.
5. If the estimated supply after adjustments was less than the estimated required capacity in the year 2060, the evaluation concluded that an additional water supply would be needed.
6. If new wells are the most feasible water management strategy, estimated at what decade it is needed and the capital cost of adding the new wells to the water system.

The methodology presented in the following text deals specifically with those entities that show a projected unmet need that is likely to be met through development of local aquifer supplies; in other words, only those entities whose needs exceed the current estimation of local groundwater supply. This does not imply that other entities that currently utilize the Carrizo Aquifer for supply will no longer do so. For example, the City of Stockdale in Wilson County utilizes a local well field in the Carrizo Aquifer to supply its needs. However, needs analysis, according to the methods employed in this study, indicate that currently-allocated groundwater supplies are sufficient to meet Stockdale's needs through 2060. Therefore, there are no projected needs and Stockdale is not specifically considered in this section. However, it is acknowledged that they will continue to use the Carrizo Aquifer as their supply, and groundwater modeling to determine the effects of proposed water management strategies will simulate all projected demands for Stockdale and other cities with similar circumstances.

For municipal entities with needs to be met from local Carrizo, TCEQ water utility data sheets were reviewed. These data sheets provide the number, depth, and reported capacity of existing wells for the city or WSC. A depth and well capacity (gpm) estimate characteristic of existing wells in the vicinity was developed for costing purposes. For actual long term average well yield, identical assumptions were made as the groundwater supply calculations. It was assumed that the well capacity (gpm) reported in the TCEQ data sheets represents a peak flow rate, and assumed a municipal peaking factor of 2. Therefore, the average yield per municipal well, expressed in acft/year, was assumed to be one-half of the reported peak value. (This assumption was not made for steam electric demands, which were based on reported historic well use, not reported peak well capacity.) No pipelines or pump stations were assumed for costing purposes. It was assumed that these proposed wells would connect directly to the local distribution system, and that the cost of any associated piping would be covered in the 35% project cost contingency factor. For the purposes of estimating well pumping power costs, a total dynamic head estimate of 300 feet was assumed: 160 feet to bring water from pumping levels to the ground surface, and 140 feet to pump into a pressurized distribution system maintained at 60 psi. This conservative estimate is intended to account for local drawdown and declining water levels with time. An assessment of likely treatment requirements based on existing water quality and treatment data was made for water from each aquifer, and costs for the appropriate level of treatment were incorporated into the cost estimate.

All cost estimates were performed according to established SB1 methodology. In other words, all costs were amortized over a 30-year loan period, with debt service and annualized O&M often being a significant proportion of costs. In addition, all wells are costed in present value, even if they are not scheduled to be needed until later decades. This is to maintain consistency in cost estimates with other projects. However, it should be noted that individual wells are not usually financed in this manner, and managers of affected municipalities and WSCs may be more interested simply in the estimated capital cost for the wells.

4C.12.1 Carrizo-Wilcox Aquifer

The following entities are expected to need new local supply wells in the Carrizo Aquifer added to their system by 2060: Benton City WSC, McCoy WSC, Atascosa County Steam Electric, City of Floresville, Oak Hills WSC, SS WSC, Sunko WSC, Gonzales WSC, Crystal Clear WSC, City of Lockhart, City of Luling, Aqua WSC, Polonia WSC. In addition, Bexar Met is planning to add water treatment facilities necessary to provide municipal water supply from its existing wells in south Bexar County. Figure 4C.12-1 presents the location of the entities with projected needs to be met from Local Carrizo Aquifer supply. Cost estimates for new wells were prepared according to the assumptions presented in the previous section. Table 4C.12-1 displays the projected needs, by decade, for each of these entities, and the decades in which additional wells are estimated to be needed. In addition the capital cost, project cost, annual cost, yield, and unit cost (in $/acft and $/1000 gallons) for water obtained under this strategy are presented in this table. However, regional water level declines in some areas may cause the system operators to lower pumps in some of their wells, and as growth in water demands occurs, it may be necessary to add wells to meet peak day demands. Water from the Carrizo-Wilcox Aquifer often has iron concentrations greater than 0.3 milligrams per liter, which exceeds guidelines for aesthetic effects. The costs of adding a water treatment plant to treat iron and manganese removal, as well as chlorination, were included in the cost estimates for these cities. Some of the well fields are located where the Carrizo Aquifer is very deep and produces relatively hot water, which may need to be cooled prior to distribution.

4C.12.2 Gulf Coast Aquifer

The City of Kenedy, in Karnes County (Figure 4C.12-2), was the only municipal system identified with projected needs that are likely to be met through local development of the Gulf Coast Aquifer. This entity is expected to need two new supply wells in the Gulf Coast Aquifer added to their system by the year 2060. Cost estimates for new wells were prepared according to the previously described methodology and are summarized in Table 4C.12-1.

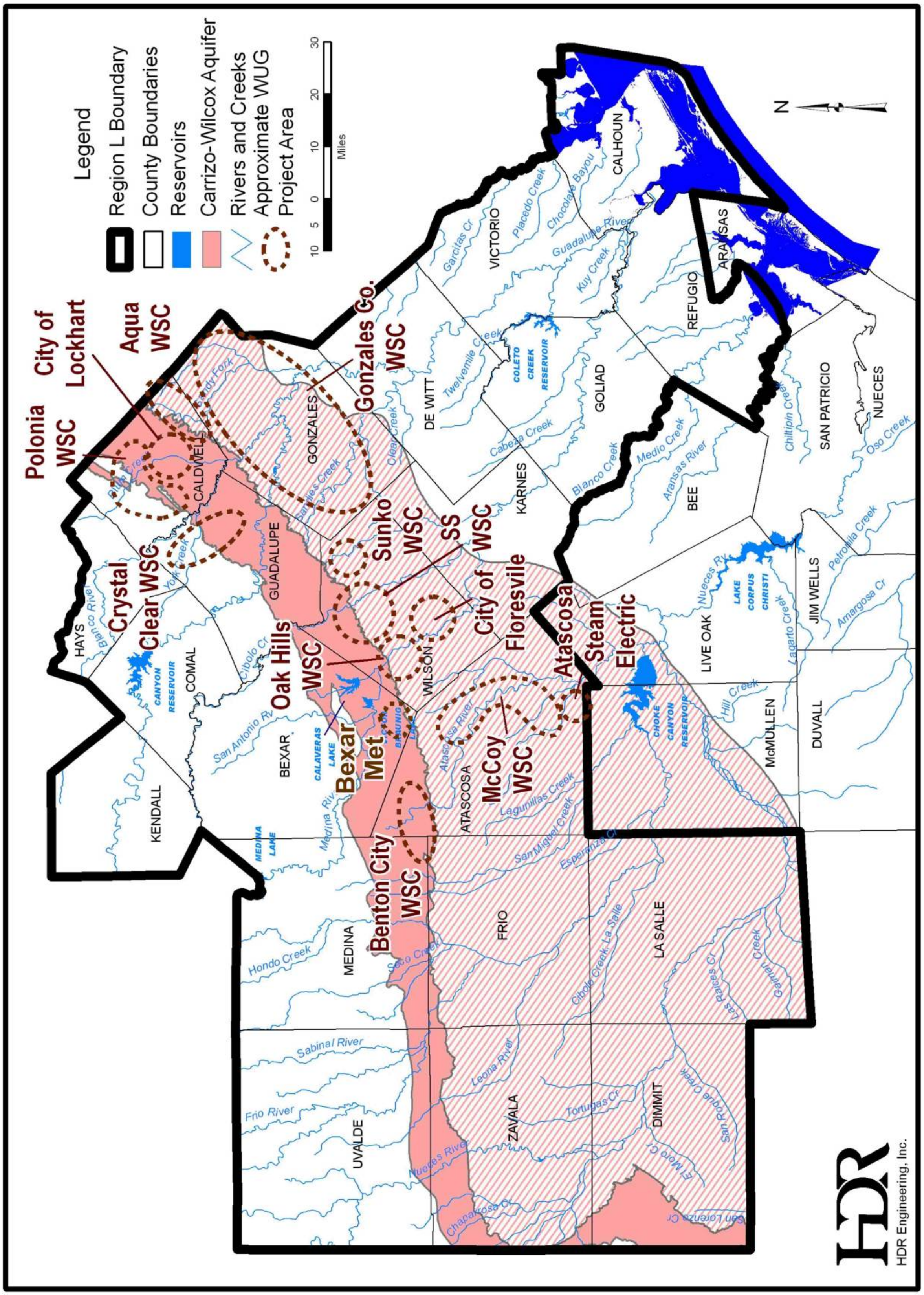


Figure 4C.12-1. Local Carrizo-Wilcox Supply

Table 4C.12-1.
Local Groundwater Water Management Strategy
Cost and Schedule Summary

User	County	Aquifer		Needs[1] 2010	2020	2030	2040	2050	2060	Total Wells	Total Capital Cost	Total Project Cost	Total Annual Cost	Available Project Yield	Annual Cost ($/acft)	Annual Cost ($/1,000 gal)
Benton City WSC	Atascosa	Carrizo	Projected Needs	0	144	385	627	869	1058	2	$1,962,000	$2,755,000	$481,000	1,613	$298	$0.92
			New Wells	*	1	*	*	1	*							
McCoy WSC	Atascosa	Carrizo	Projected Needs	515	838	1107	1321	1520	1675	3	$3,844,000	$5,397,000	$794,000	2,421	$328	$1.01
			New Wells	1	1	*	*	*	1							
Atascosa Steam Electric	Atascosa	Carrizo	Projected Needs	0	0	0	874	2212	3952	4	$4,096,000	$5,752,000	$511,000	4,480	$114	$0.35
			New Wells	*	*	*	1	1	2							
City of Floresville	Wilson	Carrizo	Projected Needs	0	0	0	0	137	411	1	$1,440,000	$2,022,000	$318,000	806	$393	$1.21
			New Wells	*	*	*	*	1	*							
Oak Hills WSC	Wilson	Carrizo	Projected Needs	0	0	81	366	673	990	2	$1,848,000	$2,595,000	$448,000	1,452	$309	$0.95
			New Wells	*	*	1	*	*	1							
SS WSC	Wilson	Carrizo	Projected Needs	223	864	1546	2214	2939	3690	5	$4,468,000	$6,274,000	$1,048,000	3,830	$274	$0.84
			New Wells	1	1	*	1	1	1							
Sunko WSC	Wilson	Carrizo	Projected Needs	0	0	0	95	237	392	1	$1,440,000	$2,022,000	$317,000	807	$392	$1.20
			New Wells	*	*	*	1	*	*							
Gonzales Co WSC	Gonzales	Carrizo	Projected Needs	0	14	75	208	254	255	1	$1,228,000	$1,725,000	$278,000	645	$431	$1.32
			New Wells	*	1	*	*	*	*							
Crystal Clear WSC[2]	Guadalupe	Wilcox	Projected Needs	0	2	494	1123	1911	2701	5	$1,983,000	$2,785,000	$355,000	1,000	$355	$1.09
			New Wells	*	1	2	2	*	*							
City of Lockhart	Caldwell	Wilcox	Projected Needs	341	984	1519	1519	1519	1519	4	$3,315,000	$4,806,000	$620,581	1,612	$385	$1.18
			New Wells	1	2	1	*	*	*							
City of Luling	Caldwell	Wilcox	Projected Needs	168	311	400	485	587	695	2	$1,340,000	$1,893,000	$292,000	807	$362	$1.11
			New Wells	1	*	*	1	*	*							
Aqua WSC	Caldwell	Carrizo-Wilcox	Projected Needs	49	121	178	240	300	362	1	$1,031,000	$1,448,000	$236,000	536	$443	$1.36
			New Wells	1	*	*	*	*	*							
Polonia WSC	Caldwell	Wilcox	Projected Needs	0	0	137	331	520	719	3	$1,561,000	$2,193,000	$312,000	720	$433	$1.33
			New Wells	*	*	1	1	1	*							
City of Kenedy	Karnes	Gulf Coast	Projected Needs	187	250	298	336	385	417	2	$3,434,000	$4,822,000	$705,000	780	$904	$2.77
			New Wells	1	*	*	*	*	1							
County Line WSC[3]	Caldwell	Trinity	Projected Needs	44	1096	1416	1582	1900	2365	2	$1,907,000	$2,693,000	$271,254	808	$336	$1.03
			New Wells	1	*	*	*	*	1							
Goforth WSC	Caldwell	Trinity	Projected Needs	400	400	400	400	400	400	1	$971,000	$1,373,000	$146,000	400	$365	$1.12
			New Wells	1	*	*	*	*	*							
Bexar Met[4]	Bexar	Trinity	Projected Needs	20,243	27,744	31,263	33,753	36,346	39,016	38	$14,455,000	$20,382,000	$4,934,000	15,000	$329	$1.01
			New Wells	10	28	*	*	*	*							
Bexar Met[5]	Bexar	Carrizo	Projected Needs	20,243	27,744	31,263	33,753	36,346	39,016	0	$1,892,000	$2,675,000	$700,000	4,000	$175	$0.54
			New Wells	*	*	*	*	*	*							
SAWS[6]	Bexar	Trinity	Projected Needs	54,406	80,254	104,433	121,980	138,954	155,967	14	$5,361,000	$7,562,000	$1,724,000	5,000	$345	$1.06
			New Wells	7	7	*	*	*	*							

Notes:
1) Indicates needs exceeding current estimate of local aquifer supply. See text for details.
2) Local Wilcox development to meet approximately 600 ac-ft/yr of needs.
3) Local Trinity development to supply approximately 808 ac-ft/yrof needs.
4) Local Trinity development to supply approximately 15,000 ac-ft/yr of needs by 2020.
5) Local Carrizo development to supply approximately 4,000 ac-ft/yr of needs by 2010. Wells already exist. Capital costs reflect treatment costs.
6) Local Trinity development to supply approximately 5,000 Ac-ft/year of needs.

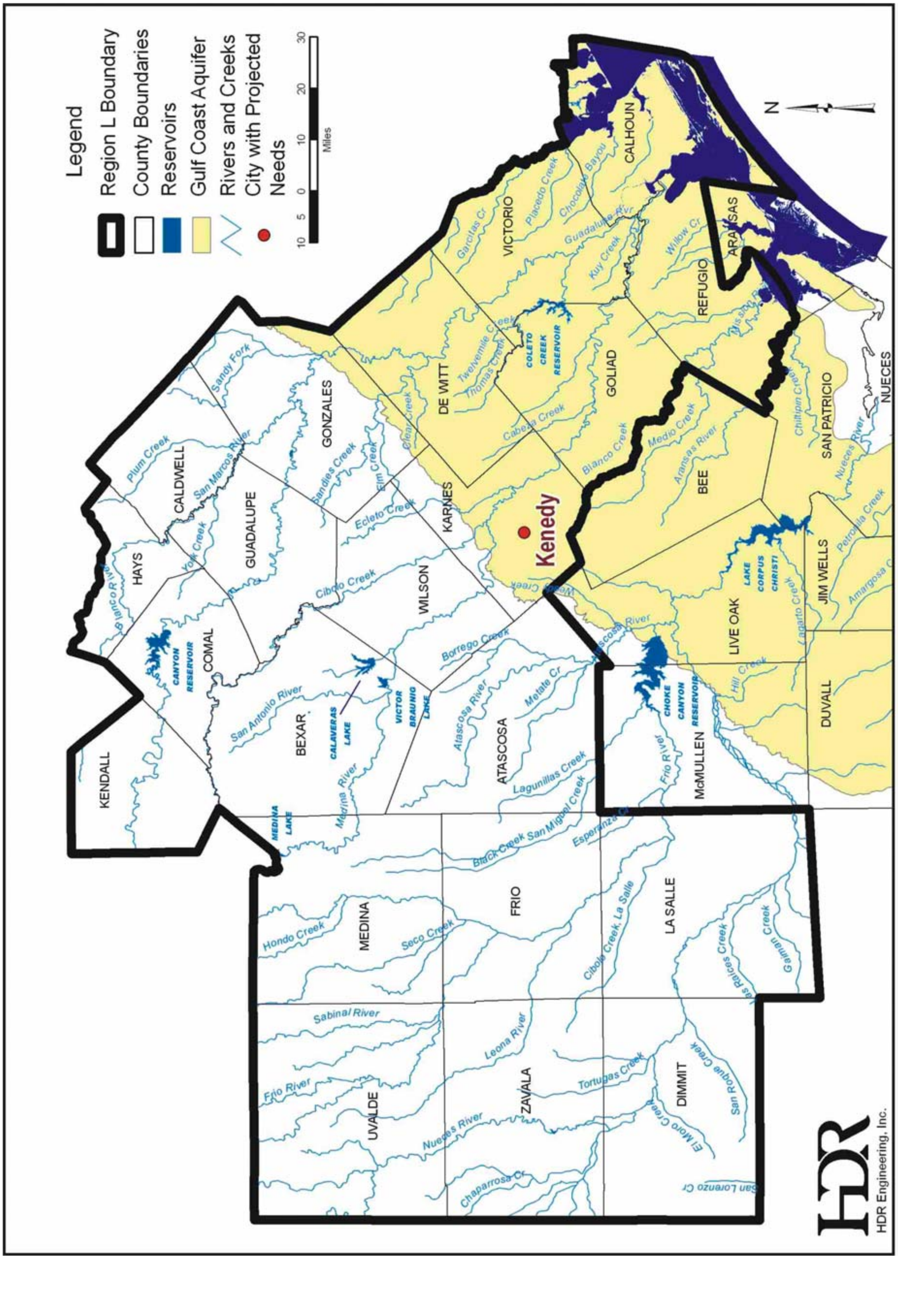


Figure 4C.12-2. Local Gulf Coast Supply

The groundwater from the Catahoula Formation has TDS concentrations greater than 1,000 ppm. Current treatment is through a reverse osmosis membrane system. Costs for this treatment were included in cost estimates.

Two other WUGs identified with major needs through 2060 were the steam-electric users in Goliad County (no needs until 2060) and the manufacturing users in Victoria County (no needs until 2040). However, it was indicated that these needs were likely to be met through a purchase from a wholesale water provider or other strategies, and not from development of local Gulf Coast supplies.

4C.12.3 Trinity Aquifer

The following entities have indicated their intent to utilize local Trinity Aquifer supplies to meet projected needs through 2060: County Line WSC, Goforth WSC, Bexar Met, and SAWS (Figure 4C.12-3). County Line WSC has plans to develop Trinity wells to supply approximately 800 acft/year from Caldwell County. Cost estimates were based on data provided by the WSC's hydrogeologist (Table 4C.12-1). SAWS and Bexar Metropolitan Water District have also indicated plans to utilize the Trinity Aquifer within Bexar County to meet projected needs. In addition to these municipal users, there are projected needs to meet livestock demands in Comal and Kendall Counties. However, wells developed to meet these needs will be private wells located at the point of demand; cost estimates for wells in the Trinity Aquifer to meet livestock needs were not developed for this plan.

Water quality in the Trinity Aquifer is generally favorable for incorporation into a water supply system with only chlorination as treatment; cost estimates for the local Trinity Aquifer projects reflect this.

4C.12.4 Barton Springs Edwards Aquifer

The Local Barton Springs Edwards water management strategy involves the phased development of new groundwater supplies from the Barton Springs Edwards Aquifer through construction of new wells and/or acquisition of rights to pump from existing wells. Planned new supplies total 150 acft/yr by 2010 and 200 acft/yr by 2050 at an estimated cost of $135/acft/yr.

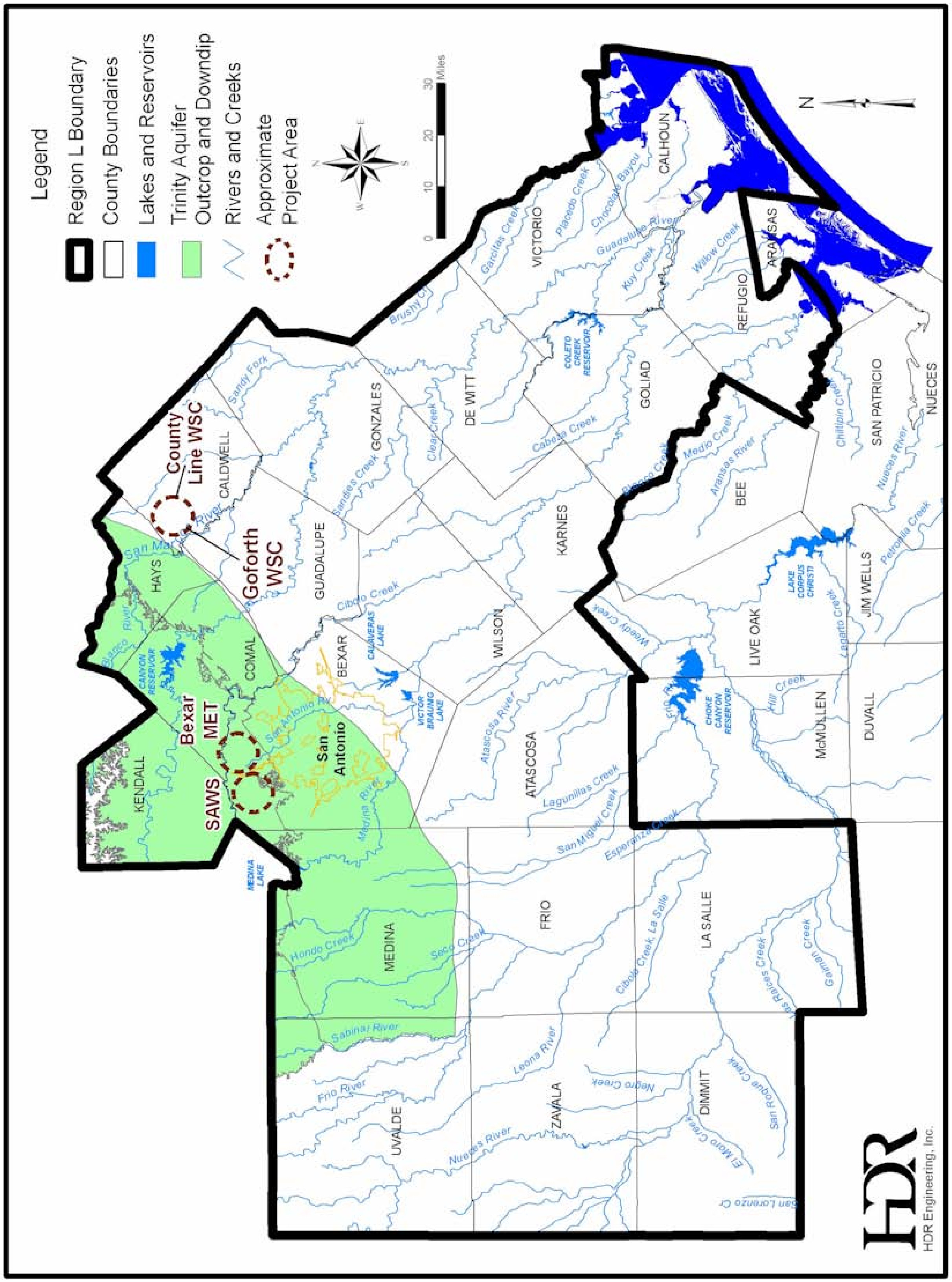


Figure 4C.12-3. Local Trinity Supply

4C.12.5 Drawdown

Predictive groundwater model simulations were performed representing projected pumpage for local supply using both the South Central Carrizo System (SCCS) groundwater model and the southern Carrizo-Wilcox/Queen City-Sparta Aquifers (SCWQSGAM). (Note: The projected local supply pumpage used for these model simulations does not include the 4,000 ac-ft/yr for the Bexar Metropolitan Water District (Bexar Met) Stagg Ranch wells in southern Bexar County, which were added to the plan in December 2005. For an indication of the drawdown effects of the BMWD Stagg Ranch wells, refer to the report section describing cumulative effects of recommended strategies (Volume I, Section 7, Figure 7.1-9). The SCWQSGAM has a larger modeled area than the SCCS model, extending all the way to the Rio Grande in the southwest. In the common area shared by both models, pumpage was identical for each county. For the area only represented in the SCWQSGAM, pumpage was consistent with groundwater usage projections developed from RWPG demand data.

Drawdown calculated by the SCCS model is displayed in Figure 4C.12-4. Drawdown calculated by the SCWQSGAM is displayed in Figure 4C.12-5. As can be seen in these figures, the SCWQSGAM calculates a greater amount of drawdown due to pumpage for local supply than does the SCCS model in the counties which are represented in both models.

Estimated projected drawdown in the Gulf Coast Aquifer due to groundwater pumpage for local supply was calculated using the publicly-released partially penetrating version of the Central Gulf Coast Groundwater Availability Model. Calculated drawdown for the Chicot and Evangeline Aquifers due to local supply pumpage is presented in Figures 4C.12-6 and 4C.12-7, respectively. Projected drawdowns in Region L counties on the Gulf Coast Aquifer are not significant over the simulated time period. It is noteworthy that the area around the City of Victoria shows *negative* drawdown of over 90 feet, indicating rising groundwater levels from 2000 conditions. This results from simulating Victoria’s proposed strategy of reducing dependence on groundwater and relying more on surface water sources. Thus a decrease in pumpage when compared to historical pumping levels results in rising groundwater elevations. This phenomenon is discussed in greater detail in Section 4C.19.

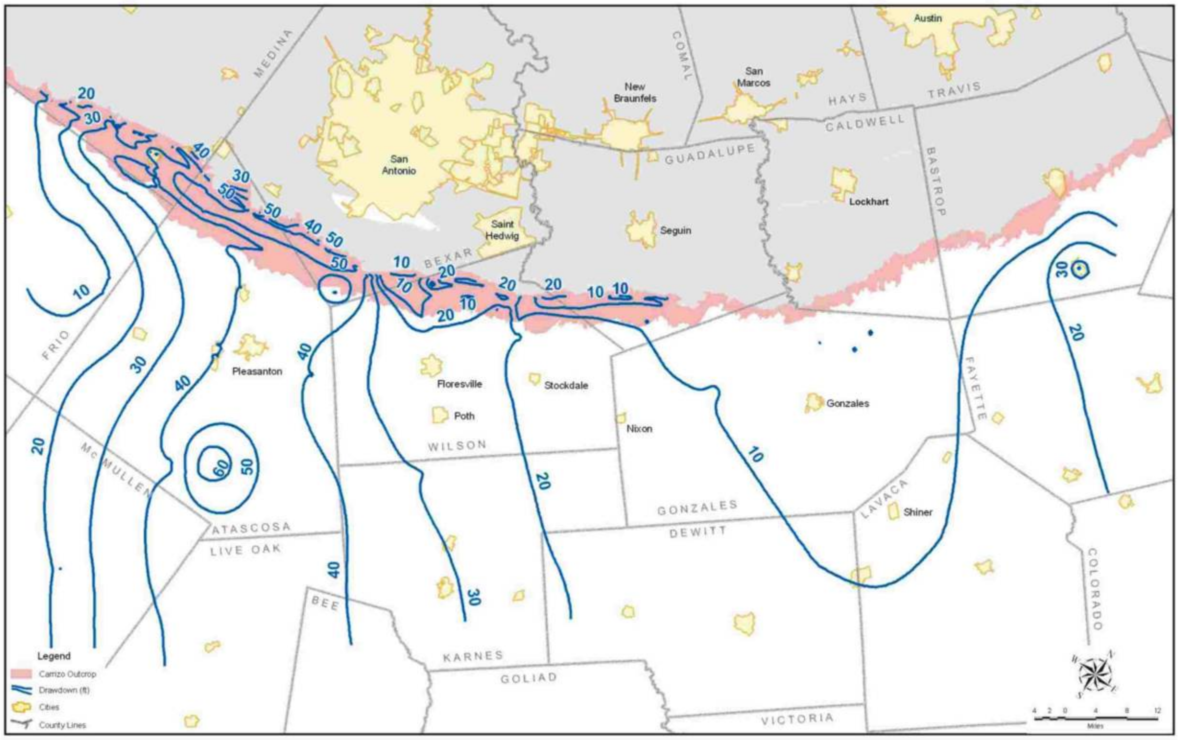


Figure 4C.12-4. SCCS Predictive Simulation Results: 2002-2060 Carrizo Drawdown due to Local Supply Pumpage

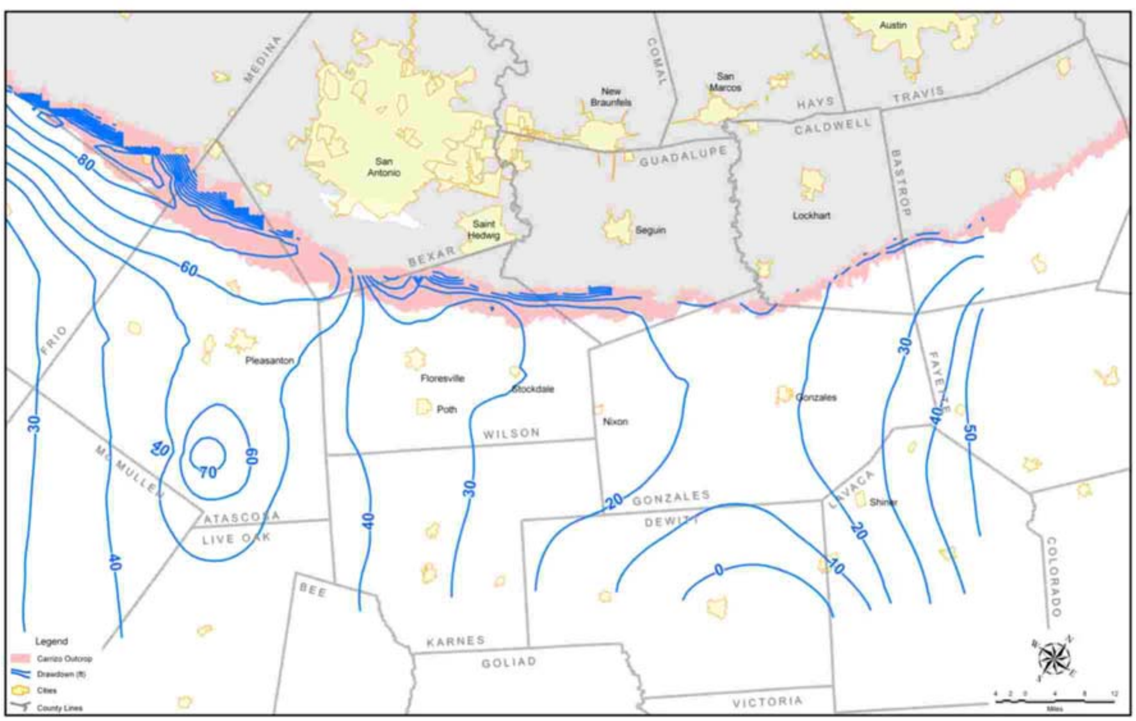


Figure 4C.12-5. SCWQSGAM Predictive Simulation Results: 2002-2060 Carrizo Drawdown due to Local Supply Pumpage

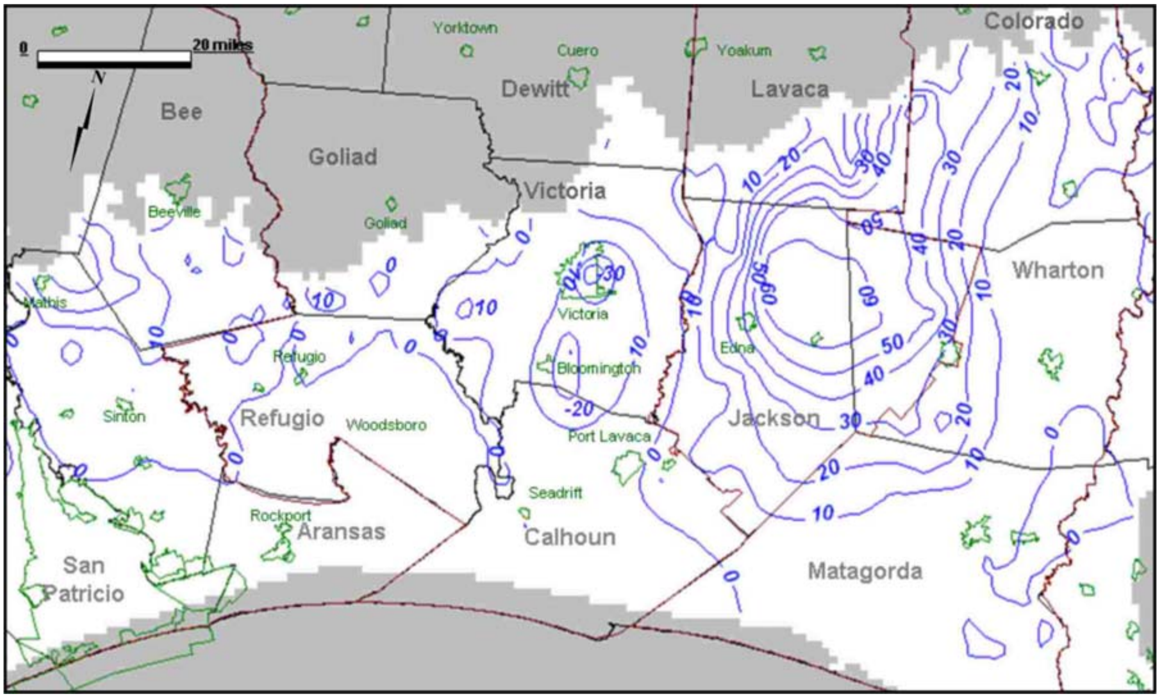


Figure 4C.12-6. Central Gulf Coast GAM Predictive Simulation Results: 2000-2060 Chicot Aquifer Drawdown due to Local Supply Pumpage

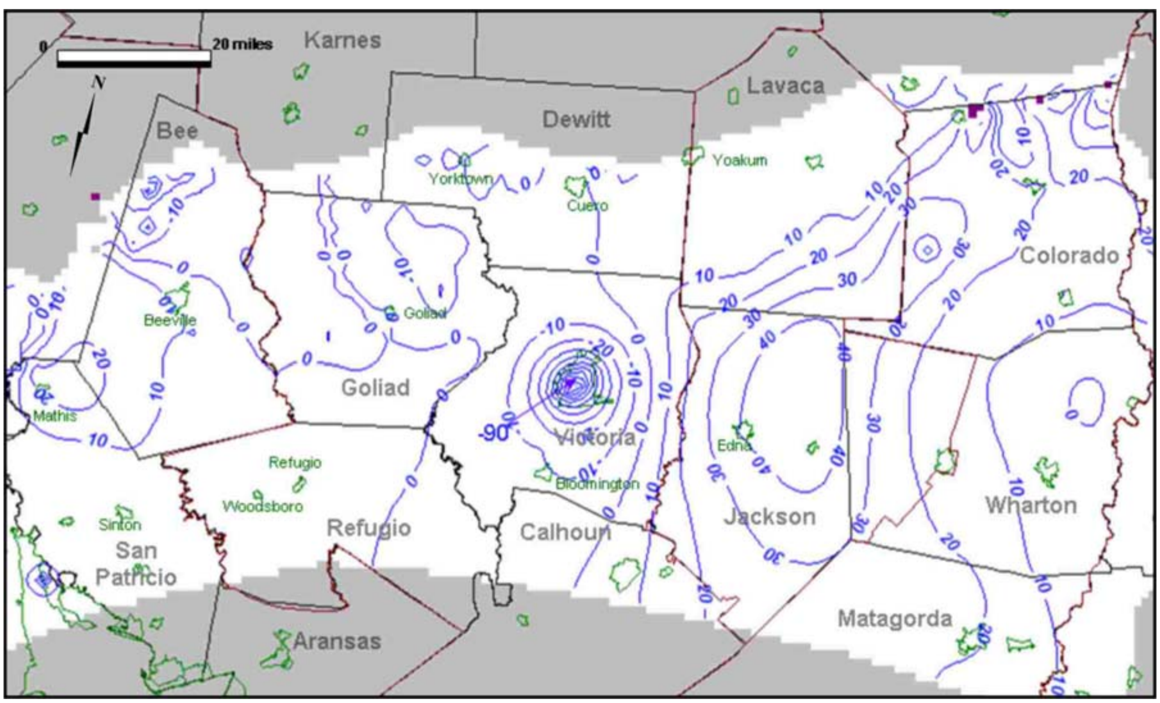


Figure 4C.12-7. Central Gulf Coast GAM Predictive Simulation Results: 2000-2060 Evangeline Aquifer Drawdown due to Local Supply Pumpage

4C.12.6 Environmental Issues

In the local groundwater water management strategy, existing municipal well fields in area that use the aforementioned aquifers for their water supply are evaluated. Some municipalities will need additional wells to meet projected water supply requirements to 2060.

Data from well fields in this area show declining trends in groundwater levels during the past 30 years. Pumping for water supply, amount of rainfall, and other factors affect aquifer levels.

The pumping of groundwater from the Carrizo-Wilcox Aquifer could have a negative impact on springflow and temporary pools in these areas. Some species inhabit or use temporary pools as well as aquifers and springs. Possible negative effects on these species should be considered when evaluating this option.

Habitat studies and surveys for protected species would need to be conducted at the proposed well field sites and along any pipeline routes. When potential protected species habitat or other significant resources cannot be avoided, additional studies would have to be conducted to evaluate habitat use or eligibility for inclusion in the National Register for Historic Places, respectively. Potential wetland impacts due to primary pipeline stream crossings can be minimized by right-of-way selection and appropriate construction methods, including erosion controls and revegetation procedures. Compensation for net losses of wetlands would be required where impacts are unavoidable.

4C.12.7 Engineering and Costing

A summary of projected needs and cost estimates for development of local groundwater supply in the three subject aquifers, subject to the assumptions previously discussed, is presented in Table 4C.12-1.

4C.12.8 Implementation Issues

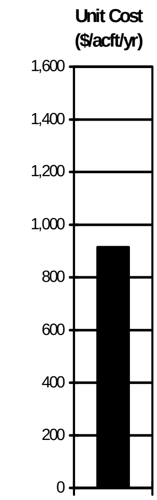
The development of additional wells and well fields in the Carrizo-Wilcox Aquifer in the South Central Texas Water Planning Region may encounter the following issues:

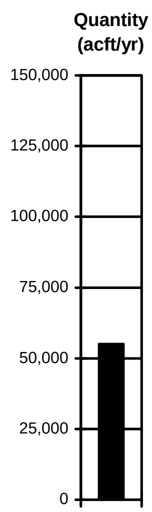
- Detailed feasibility evaluation including test drilling and aquifer water quality testing.
- Impact on:
  - Endangered and threatened species,
  - Water levels in the aquifer,

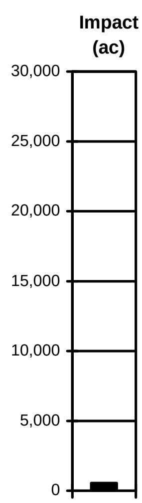
  - Baseflow in streams, and
  - Wetlands.
- Competition with others for groundwater in the area.
- Regulations by Groundwater Conservation Districts, including the renewal of pumping permits at periodic intervals in counties where districts have been organized.

(This page intentionally left blank.)

2006 South Central Texas Regional Water Plan
Water Management Strategy Summary Sheet







Name: **Simsboro Aquifer with Delivery to Central Bexar County via the Northern Pipeline Route**

Description: Strategy involves the phased development and expansion of well fields in the Simsboro Aquifer in Milam, Lee, and Bastrop Counties for the purposes of facilitating ongoing mining operations and production of municipal and industrial water supply. Facilities include 120 wells, well field collection systems, a 54-inch water transmission pipeline delivering water a distance of approximately 107 miles to central Bexar County, a new water treatment plant, and distribution system improvements for integration of the additional supply. Supplies are available pursuant to contractual agreements between ALCOA, SAWS, and CPS.

***Decade Needed*:** Not recommended to meet projected needs.

Cost, Quantity of Water, and Land Impacted

Unit Cost of Water:	**914**	**$/acft/yr**	**Treated Water Delivered**
Quantity of Water:	**55,000**	**acft/yr**	**Reliability = Firm**
Land Impacted:	**541**	**acres[1]**	**[1]Mine property and well field excluded**

Additional Considerations per Regional Water Planning Guidelines

Environmental Factors:

Well field operations may impact Houston Toad habitat.

Impacts on Water Resources:

Long-term reductions in aquifer levels, minimal reductions in instream flow at outcrop, and potential effects on discharge of small springs.

Impacts on Agricultural & Natural Resources:

Current discharge of groundwater to surface streams (dewatering to facilitate mining) likely to be reduced or cease. Potential changes to aquatic or riparian habitat.

Other Relevant Factors per SCTRWPG:

Beneficial use of groundwater now unused. Planned Bastrop Co. supply for Region L may exceed availability per Region K.

Comparison of Strategies to Meet Needs:

Moderate unit cost. No conflicts with other recommended water management strategies.

Interbasin Transfer Issues:

Groundwater conservation district rules and permits.

Third-Party Impacts of Voluntary Transfers:

Limited transfer to avoid potential socio-economic impacts.

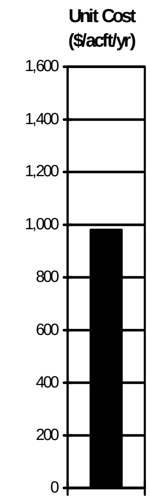
Regional Efficiency:

Beneficial use of groundwater currently produced, but unused. Water trade opportunities may exist with wholesale water providers along the I-35 corridor.

Water Quality Considerations:

None of significant concern.

2006 South Central Texas Regional Water Plan
Water Management Strategy Summary Sheet



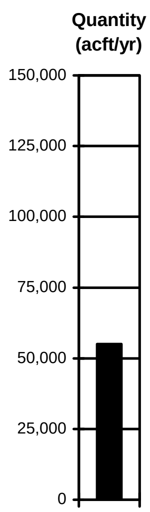
Name: **Simsboro Aquifer with Delivery to South Bexar County via the Southern Pipeline Route**

Description: Strategy involves the phased development and expansion of well fields in the Simsboro Aquifer in Milam, Lee, and Bastrop Counties for the purposes of facilitating ongoing mining operations and production of municipal and industrial water supply. Facilities include 120 wells, well field collection systems, a 54-inch water transmission pipeline delivering water a distance of approximately 143 miles to south Bexar County, expansion of the existing Twin Oaks Water Treatment Plant, and distribution system improvements for integration of the additional supply. Supplies are available pursuant to contractual agreements between ALCOA, SAWS, and CPS.

***Decade Needed*:** Not recommended to meet projected needs.

Cost, Quantity of Water, and Land Impacted

Unit Cost of Water:	**980**	**$/acft/yr**	**Treated Water Delivered**
Quantity of Water:	**55,000**	**acft/yr**	**Reliability = Firm**
Land Impacted:	**248**	**acres[1]**	**[1]Mine property, well field, and shared right-of-way w/ SAWS Regional Carrizo Project excluded.**



Additional Considerations per Regional Water Planning Guidelines

Environmental Factors:

Well field operations may impact Houston Toad habitat.

Impacts on Water Resources:

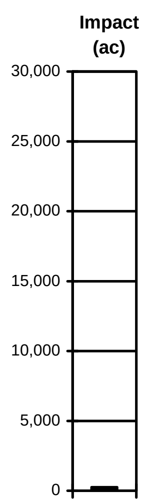
Long-term reductions in aquifer levels, minimal reductions in instream flow at outcrop, and potential effects on discharge of small springs.

Impacts on Agricultural & Natural Resources:

Current discharge of groundwater to surface streams (dewatering to facilitate mining) likely to be reduced or cease. Potential changes to aquatic or riparian habitat.

Other Relevant Factors per SCTRWPG:

Beneficial use of groundwater now unused. Planned Bastrop Co. supply for Region L may exceed availability per Region K.



Comparison of Strategies to Meet Needs:

Moderate unit cost. No conflicts with other recommended water management strategies.

Interbasin Transfer Issues:

Groundwater conservation district rules and permits.

Third-Party Impacts of Voluntary Transfers:

Limited transfer to avoid potential socio-economic impacts.

Regional Efficiency:

Beneficial use of groundwater currently produced, but unused. Shared right-of-way with SAWS Regional Carrizo Project.

Water Quality Considerations:

None of significant concern.

4C.13 Simsboro Aquifer

4C.13.1 Description of Water Management Strategy

The Simsboro Aquifer in Central Texas is part of the Carrizo-Wilcox Aquifer System and is capable of producing large quantities of freshwater. The aquifer has primarily been used for domestic, livestock, and public supplies, except in southwestern Milam County where lignite mining in the overlying Calvert Bluff Formation requires the aquifer to be depressurized. Since 1988, the depressurization operations have pumped about 30,000 acft/yr from the Simsboro Aquifer and have discharged much of the water to East Yegua Creek. Over the next few decades, the mining operators are planning to advance the lignite mines southwestward into western Lee and northern Bastrop Counties. A well field intended for depressurization purposes in these expanded mining operations, as well as additional water being pumped from wells in the vicinity of the present mining operations, results in a line of production wells that extends from south of U.S. Hwy 79 near Rockdale to north of U.S. Hwy 290 near Elgin, a distance of about 30 miles (see Figure 4C.13-1).

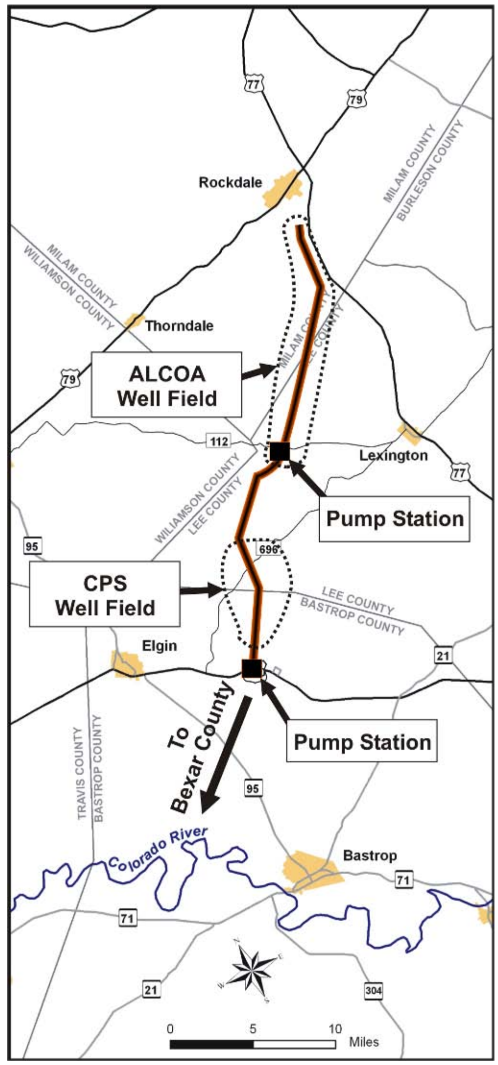


Figure 4C.13-1. ALCOA and CPS Well Fields and Water Collection System

The placement and operation of wells for supplies to be used in this water management strategy for the South Central Texas Water Planning Region would be coordinated with mining operators so that the wells would effectively depressurize the aquifer and provide water for municipal and industrial purposes. The water quality of the Simsboro Aquifer is suitable for use as a public water supply, except for elevated concentrations of iron and manganese.

Even though mining operations may require some of the supply wells to be abandoned and replaced at another location from time-to-time, for planning purposes, only one well field development scenario is planned. With a proposed transfer of 55,000 acft/yr to the South Central Texas Water Planning Region and average well yields from the Simsboro Aquifer of about 300 gpm in the proposed well field, 120 wells would be required, including a contingency of 10 percent for wells being out-of-service. In general, the supply wells would be spaced about 1,000 feet apart, parallel the outcrop of the Simsboro, and located downdip of the outcrop.

There are two pipeline delivery options for the water supply to Bexar County. The northern pipeline option delivers water to central Bexar County via a 107-mile, 54-inch pipeline. The southern pipeline option delivers water to the existing Twin Oaks water treatment and distribution facility in southern Bexar County via a 143-mile, 54-inch pipeline. Both options use the same well field and transmission design to a location south of the Colorado River in Bastrop County. At this location, the northern pipeline option would take a direct route to Bexar County and pass near Lockhart and Seguin. The southern pipeline option turns south toward northern Gonzales County and utilizes a right-of-way to southern Bexar County that was selected for another water management strategy (identified as Regional Carrizo for Bexar County Supply). Figures 4C.13-2 and 4C.13-3 show the approximate locations of the pipeline routes, water treatment plant (50 MGD), and delivery points. The water is assumed to be delivered at a uniform rate and treated for iron and manganese removal at the terminus.

4C.13.2 Available Yield

Evaluations of this water management strategy are based on two groundwater availability studies.[1,2] These studies indicate that, in the project area, about 2,500 acft/yr of groundwater can be developed per mile along the outcrop of the Simsboro Aquifer. Considering a 30-mile section of the Carrizo-Wilcox Aquifer from U.S. Hwy 79 near Rockdale to U.S. Hwy 290 near Elgin, about 75,000 acft/yr could be developed. After making an allowance for local groundwater use, 55,000 acft/yr could be developed and transported to the South Central Texas Water Planning Region. Based on model simulations with the TWDB's Central Carrizo-Wilcox Groundwater

[1] HDR Engineering, Inc., "Assessment of Groundwater Availability on CPS Property in Bastrop and Lee Counties, Texas," prepared for San Antonio Water System, San Antonio, Texas, July 1999.
[2] Dutton, Alan R. and Others, "Groundwater Availability Model for the Central Part of the Carrizo-Wilcox Aquifer in Texas," prepared for Texas Water Development Board, February 2003.

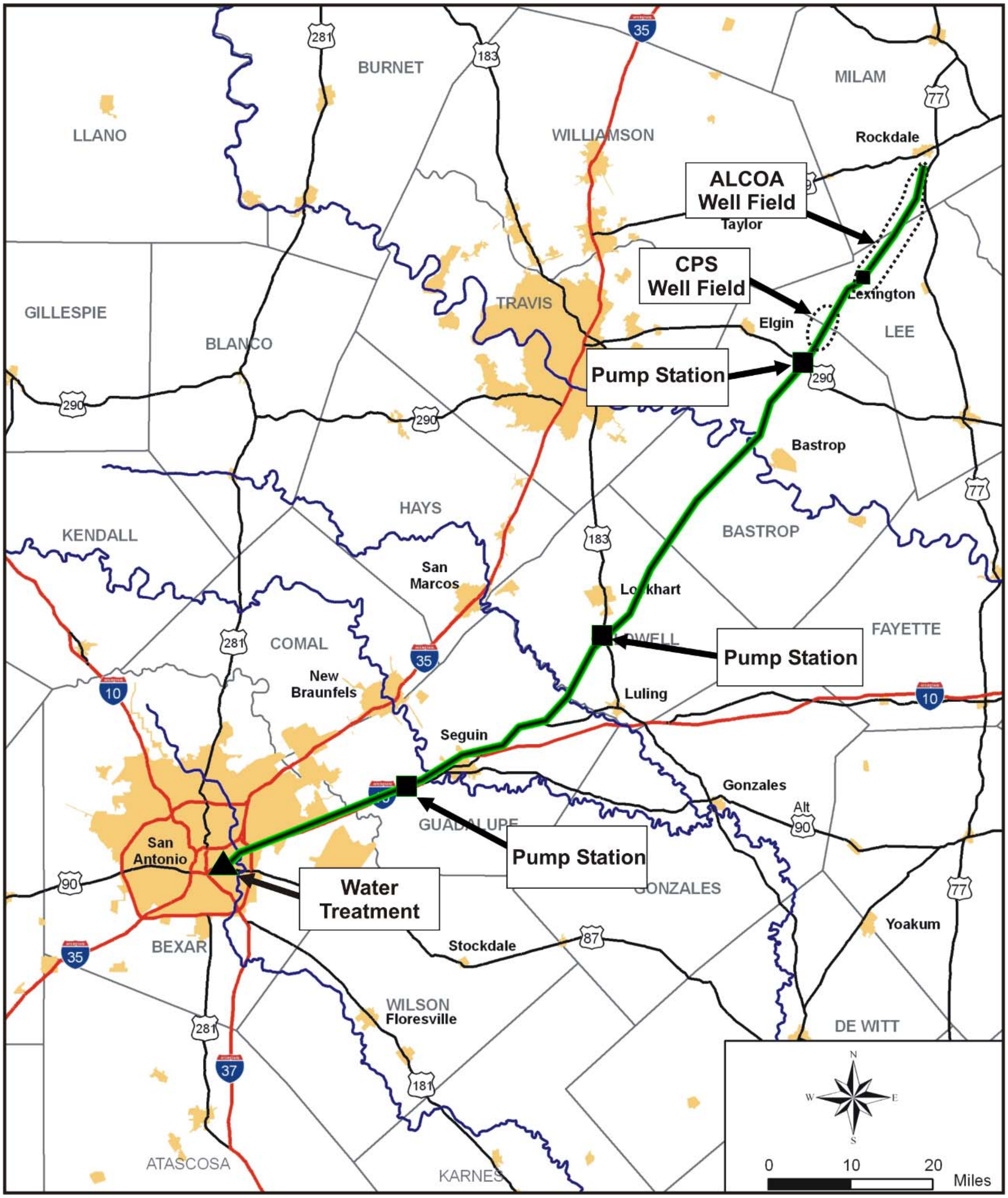


Figure 4C.13-2. Location of Water Delivery Route and Facilities for Simsboro Aquifer Groundwater to Central Bexar County via the Northern Pipeline Option

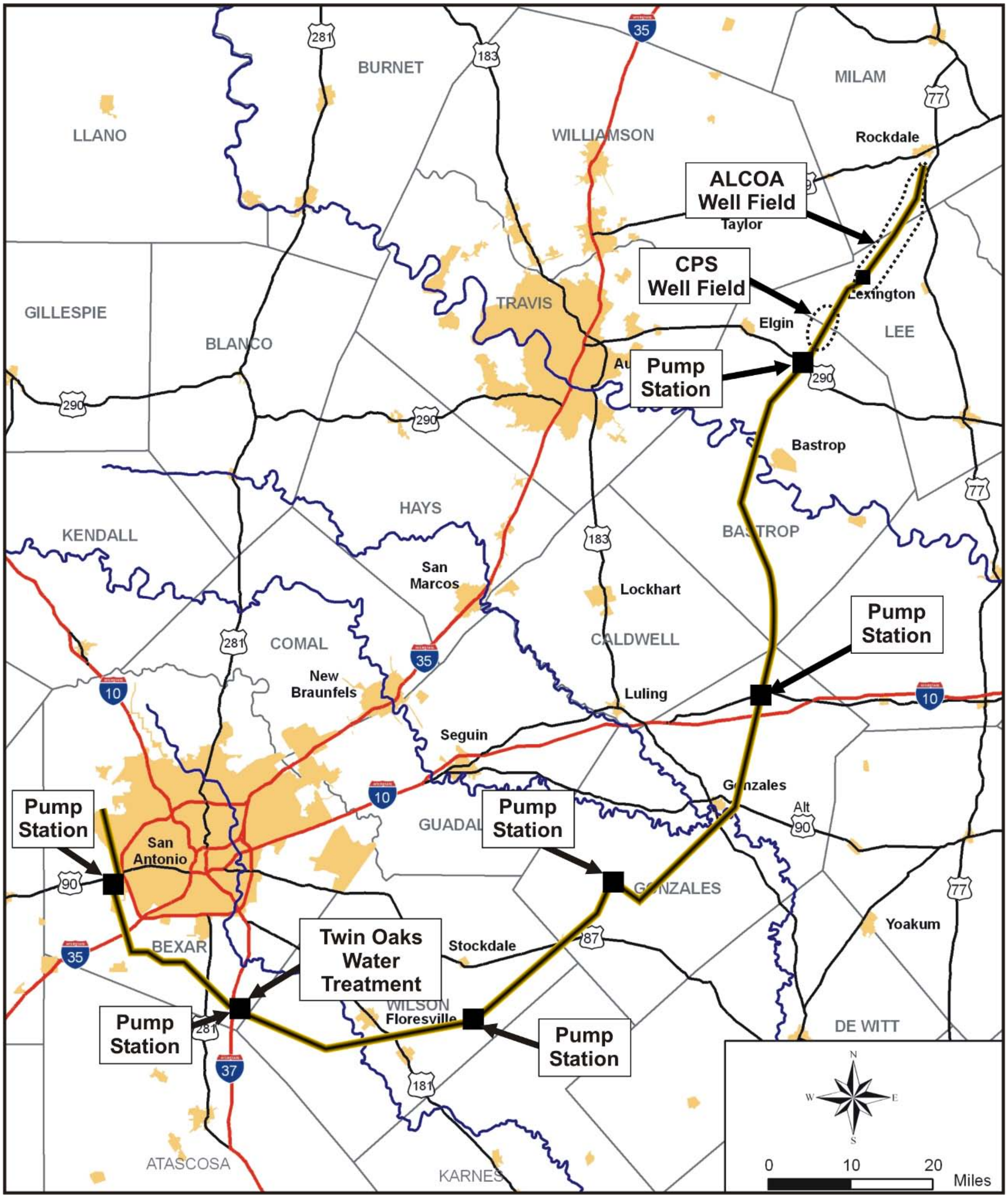


Figure 4C.13-3. Location of Water Delivery Route and Facilities for Simsboro Aquifer Groundwater to Southern Bexar County via the Southern Pipeline Option

Availability Model (GAM) using groundwater availability estimates adopted by the Brazos G Regional Water Planning Group, water level drawdowns in the well field could range from 100 feet to about 200 feet.

4C.13.3 Environmental Issues

The Simsboro Aquifer water management strategy involves the construction of a 30-mile well field in Milam, Lee, and Bastrop Counties. The northern well field has existed for many years, and the central and southern part of the well field will be implemented in the near future to support lignite mining, and is presumed to be needed for that purpose regardless of whether the water is transferred to the South Central Texas Water Planning Region. From the U.S. 290 pump station at the southern end of the well field, northern option requires a 107-mile pipeline, and the southern option requires a 143-mile pipeline. Intermediate pump stations and water treatment facilities at the terminus are required for both options.

The majority of the well field and the extensions of the transmission pipeline for both options lie in and along several borders of the Blackland Prairies and Post Oak Savannah vegetational areas.[3] The project area would lie in the Texas Blackland Prairies and East Central Texas ecoregions.[4] The pipeline routes cross the Texan biotic province and a small portion of the Tamaulipan biotic province.[5]

The dominant vegetation of the Blackland Prairies is mesquite, post oak, bluestems, switchgrass and blackjack supported by clay soils mixed with sandy loams. The Post Oak Savannah vegetational area is characterized by gently rolling to hilly terrain with an understory that is typically tall grass and an overstory that is primarily post oak *(Quercus stellata)* and blackjack oak *(Q. marilandica)*. On-site surveys will be necessary to determine fauna composition since the pipeline corridor is a mosaic of the Post Oak Savannah and the Blackland Prairie ecoregions and could potentially include a wide variety of species. The pipeline routes cross the San Marcos River and Geronimo Creek, both listed by Texas Parks and Wildlife as Ecologically Significant River and Stream Segments.

[3] Omernik, James M., “Ecoregions of the conterminous United States,” Annals of the Association of American Geographers, 77(1) pp. 118-135.
[4] Gould, F.W., “The Grasses of Texas,” Texas A&M University Press, College Station, Texas, 1975.
[5] Blair, W.F., “The biotic Provinces of Texas,” Texas Journal of Science 2(1): pp. 93-117, 1950.

Table 4C.13-1 lists rare and protected species that may have habitat in the project area. The Texas Biological and Conservation Data System maintained by TPWD Wildlife Diversity Branch maps several species and essential habitat in the vicinity of the well field and transmission pipelines. Houston Toad *(Bufo houstonensis)* habitat is mapped in Lee and Bastrop Counties along with several sightings of the species itself, and a portion of this habitat is less than a mile from the proposed project area. The well field and resulting water table drawdown could potentially impact Bufo houstonensis in this area since the endangered Houston Toad uses the temporary pools provided by the saturated sands of the Carrizo Aquifer as their breeding habitat. Two threatened species, Cagles Map Turtle (Graptemys caglei), and the Bald Eagle (Haliaeetus leucocephalus), were reported very near the transmission pipeline route. The Bald Eagle prefers habitat near large bodies of water with nearby resting sites, and the map turtle is found in the waters of the Guadalupe River Basin. In addition to these species, pipelines would pass in the vicinity of several mapped rare species: Guadalupe Bass *(Micropterus treculi)*, Mountain Plover *(Charadrius montanus)*, Parks jointweed (*Polygonella parksii*), Sandhill woollywhite (*Hymenopappus carrizoanus*), Elmendorf's Onion (*Allium elmendorfii*), Texas tauschia (Tausc*hia texana*), Texas Garter Snake (*Thamnophis sirtalis annectens)* and Bracted Twistflower *(Streptanthus bracteatus)*.

Several protected species that were not specifically mapped along the proposed well field or pipeline route, but may have essential habitat in the project area include the Timber/Canebrake Rattlesnake, Texas Tortoise, and the Spot-tailed Earless Lizard. The Timber Rattlesnake and Spot-tailed Earless Lizard can be found in woodlands consisting of oak and other hardwoods; the Texas Tortoise prefers open brush with grass understory and usually occupies shallow depressions at the base of a bush or cactus. The endangered Navasota ladies' tresses *(Spiranthes parksii)*, grows at the margins of post oak woodlands within sandy loams and may be affected by construction.

Protected bird species, which may have habitat within the study area, are the Golden-cheeked Warbler *(Dendroica chrysoparia)*, Black-capped Vireo *(Vireo atricapillus)*, and Zone-tailed Hawk (*Buteo albonotatus)*. The Golden-cheeked Warbler inhabits mature oak-Ashe juniper woods for nesting. It requires strips of Ashe juniper bark for nest material. The Black-capped Vireo nests in dense underbrush in semi-open woodlands having distinct upper and lower

Table 4C.13-1.
Important Species* Having Habitat or Known to Occur in Counties Potentially Affected by Option Simsboro Aquifer – Bastrop, Lee, and Milam Counties

Common Name	Scientific Name	Impact Value	Multiplier Based on Status	Adjusted Impact	Summary of Habitat Preference	Listing Entity		Potential Occurrence in County
						USFWS[1]	TPWD[1]	
American Peregrine Falcon	*Falco peregrinus anatum*	0	3	0	Open country; cliffs	DL	E	Nesting/Migrant
Arctic Peregrine Falcon	*Falco peregrinus tundrius*	0	2	0	Open country; cliffs	DL	T	Nesting/Migrant
Bald Eagle	*Haliaeetus leucocephalus*	1	2	2	Large bodies of water with nearby resting sites	LT-PDL	T	Nesting/Migrant
Big Red Sage	*Salvia penstemonoides*	1	1	1	Endemic; Creekbeds and seepage slopes of limestone canyons			Resident
Black Bear	*Usus americanus*	0	2	0	Mountains, broken country, woods, brushlands, forests	T/SA; NL	T	Resident
Black-capped Vireo	*Vireo atricapillus*	1	3	3	Semi-open broad-leaved shrublands	LE	E	Nesting/Migrant
Black-spotted Newt	*Notophthalmus meridionalis*	1	2	3	Wet or temporally wet arroyos, canals, ditches, shallow depressions; aestivates underground during dry periods		T	Resident
Blue Sucker	*Cycleptus elongatus*	0	2	0	Channels and flowing pools with exposed bedrock		T	Resident
Bracted Twistflower	*Streptanthus bracteatus*	1	1	1	Endemic; Shallow clay soils over limestone; rocky slopes			Resident
Braken Bat Cave Meshweaver	*Cicurina venii*	0	3	0	Small eyeless spider, in Karst features in western Bexar County.	LE		Resident
Cagle's Map Turtle	Graptemys caglei	1	2	2	Waters of the Guadalupe River Basin	C1	T	Resident

Table 4C.13-1 (Continued)

Cave Myotis Bat	Myotis velifer	0	1	0	Colonial & cave dwelling; hibernates in limestone caves of Edwards Plateau			Resident
Cokendolpher Cave Harvestman	*Texella cokendolpheri*	0	3	0	Small eyeless harvestman, karst features in north-central Bexar county.	LE		Resident
Comal Blind Salamander	*Eurycea tridentifera*	0	2	0	Endemic; Semi-troglobitic; Springs and waters of caves		T	Resident
Correll's False Dragon-Head	*Physostegia correllii*	0	1	0	Wet soils			Resident
Edwards Plateau Spring Salamander	*Eurycea sp. 7*	0	1	0	Troglobitic; Edwards Plateau			Resident
Elliot's Short-tailed Shrew	*Blarina hylophaga hylophaga*	0	1	0	Sandy areas in live oak mottes.			Resident
Elmendorf's Onion	*Allium elmendorfii*	1	1	1	Endemic; deep sands derived from Queen City and similar Eocene formations			Resident
Golden-Cheeked Warbler	*Dendroica chrysoparia*	1	3	3	Woodlands with oaks and old juniper	LE	E	Nesting/Migrant
Government Canyon Bat Cave Meshweaver	*Cicurina vespera*	0	3	0	Small, eyeless spider, karst features in northwestern Bexar County.	LE		Resident
Government Canyon Bat Cave Spider	*Neoleptoneta microps*	0	3	0	Small, eyeless or essentially eyeless spider; karst features in N and NW Bexar Co.	LE		Resident
Ground Beetle #1	*Rhadine exilis*	0	3	0	Eyeless beetle, karst features in northern Bexar County.	LE		Resident

Table 4C.13-1 (Continued)

Ground Beetle #2	*Rhadine infernalis*	0	3	0	Small eyeless ground beetle; karst features in northern and western Bexar County.	LE		Resident
Guadalupe Bass	*Micropterus treculi*	1	1	1	Streams of eastern Edwards Plateau			Resident
Guadalupe Darter	*Percina sciera apristis*	0	1	0	Raceways of medium streams and rivers.			
Helotes Mold Beetle	*Bastrisodes venyivi*	0	3	0	Small, essentially eyeless mold beetle; karst features in N and NW Bexar Co.	LE		Resident
Henslow's Sparrow	*Ammodramus henslowii*	0	1	0	Weedy fields or cut over areas; bare ground for running and walking			Nesting/Migrant
Houston Toad	*Bufo houstonensis*	2	3	6	Loamy, friable soils, temporary rain pools, flooded fields, ponds surrounded by forest or grass; reintroduced to Colorado Co.	LE	E	Resident
Indigo Snake	*Drymarchon corais erebennus*	1	2	2	Grass prairies and sand hills; usually thornbush woodland and mesquite savannah of coastal plain		T	Resident
Interior Least Tern	*Sterna antillarum athalassos*	0	3	0	Inland river sandbars for nesting and shallow waters for foraging	LE	E	Nesting/Migrant
Jaguarundi	*Felis yagouaroudi*	1	3	3	South Texas thick brushlands, favors areas near water	LE	E	Resident
Keeled Earless Lizard	*Holbrookia propinqua*	1	1	1	Coastal dunes, Barrier islands and sandy areas			Resident
Manfreda Giant-Skipper	*Stallingsia maculosus*	0	1	0	Larvae feed inside leaf shelter and pupae found in cocoon made of leaves fastened by silk			Resident
Madla's Cave Spider	*Cicurina madla*	0	3	0	Small, eyeless or essentially eyeless spider; karst features in N and NW Bexar Co.	LE		Resident
Mimic Cavesnail	*Phreatodrobia imitata*	0	1	0	Subaquatic; wells in Edwards Aquifer			Resident
Mountain Plover	*Charadrius montanus*	1	1	1	Shortgrass plains and fields, sandy deserts, plowed fields			Nesting/Migrant
Navasota Ladies'-Tresses	*Spiranthes parksii*	1	3	3	Margins of post oak woodlands within sandy loams	LE	E	Resident

Table 4C.13-1 (Continued)

Ocelot	*Felis pardalis*	1	3	3	Dense chaparral thickets; mesquite-thorn scrub and live oak mottes; avoids open areas	LE	E	Resident
Palmetto Pill Snail	*Euchemotrema leai cheatumi*	0	1	0	Terrestrial snail from Palmetto State Park.			Resident
Parks' Jointweed	*Polygonella parksii*	1	1	1	South Texas Plains; subherbaceous annual in deep loose sands, spring-summer			Resident
Plains Spotted Skunk	*Spilogale putorius interrupta*	0	1	0	Catholic; Wooded, brushy areas and tallgrass prairies			Resident
Red Wolf	*Canis rufus*	1	3	3	Extirpated	LE	E	
Robber Baron Cave Spider	*Cicurina baronia*	0	3	0	Small, eyeless or essentially eyeless spider; karst features in N and NW Bexar Co.	LE		Resident
Sandhill Woolywhite	*Hymenopappus carrizoanus*	1	1	1	Endemic; Open areas in deep sands derived from Carrizo and similar Eocene formations			Resident
Sharpnose Shiner	*Notropis oxyrhynchus*	0	1	0	Endemic to Brazos River drainage.	C1		Resident
Smalleye Shiner	*Notropis buccula*	0	1	0	Endemic to upper Brazos River system	C1		Resident
Spikerush	*Eleocharis austrotexana*	0	1	0	Plant			Resident
Spot-tailed Earless Lizard	*Holbrookia lacerata*	1	1	1	Oak-juniper woodlands and mesquite-prickly pear			Resident
Texas Tauschia	*Tauschia texana*	1	1	1	Plant.			Resident
Texas Garter Snake	*Thamnophis sirtalis annectens*	1	1	1	Varied, especially wet areas; bottomlands and pastures			Resident
Texas Horned Lizard	*Phrynosoma cornutum*	1	2	2	Varied, sparsely vegetated uplands		T	Resident
Texas Salamander	*Eurycea neotenes*	0	1	0	Endemic, from springs, seeps and caves.			Resident
Texas Tortoise	*Gopherus berlandieri*	1	2	2	Open brush with grass understory; open grass and bare ground avoided; occupies shallow depressions at base of bush or cactus, underground burrows, under objects; active March-Nov		T	Resident
Timber/Canebrake Rattlesnake	*Crotalus horridus*	1	2	2	Bottomland hardwoods		T	Resident
Toothless Blindcat	*Trogloglanis pattersoni*	1	1	1				Resident
Whooping Crane	*Grus americana*	0	3	0		LE	E	Migrant

Table 4C.13-1 (Continued)

White-faced Ibis	*Plegadis chihi*	0	2	0			T	
Widemouth Blindcat	*Satan eurystomus*	1	1	1				Resident
Wood Stork	*Buteo americana*	1	2	2			T	Nesting/Migrant
Zone-tailed Hawk	*Buteo albonotatus*	1	2	2			T	Nesting/Migrant

[1] Texas Parks and Wildlife Department (TPWD), Unpublished 2005, March 2005, Data and Map Files of the Wildlife Science Research and Diversity Division maintained by TPWD, Austin, Texas.

* LE/LT=Federally Listed Endangered/Threatened E/SA, T/SA=Federally Listed Endangered/Threatened by Similarity of Appearance
C1=Federal Candidate for Listing DL, PDL=Federally Delisted/Proposed for Delisting NL=not Federally Listed E, T=State Listed Endangered/Threatened
PE, PT=Federally Proposed Endangered/ Threatened Blank = Rare, but no regulatory listing status

stories, while the Zone-tailed Hawk inhabits arid, open country including deciduous or pine-oak woodlands.

Two fish species that could be affected by the delivery pipeline are the Toothless Blindcat *(Trogloganis pattersoni)* and Widemouth Blindcat *(Satan eurystomus)*, which live in caves found in the Edwards Aquifer at the end of the northern pipeline route.

Existing regulations would require that habitat studies and surveys for protected species be conducted at the proposed well field sites, construction activity sites, and along any pipeline routes. Monitoring saturated sands of the Carrizo Aquifer for effects by pumping groundwater may be required to protect the Houston Toad habitat. When potential protected species habitat or other significant resources cannot be avoided, additional studies would be required to evaluate habitat use, permit requirements, and other mitigative measures. Eligibility for inclusion in the National Register for Historic Places would be considered for migration of cultural resources that could not be avoided. Wetland impacts, primarily pipeline stream crossings, can be minimized by right-of-way selection and appropriate construction methods, including erosion controls and revegetation procedures. Compensation for net losses of wetlands would be required where impacts are unavoidable.

Based on the review of available records housed at the Texas Archeological Research Laboratory in Austin, 113 cultural resource sites appear to occur within the project area that extends from south of U.S. Hwy 79 near Rockdale to north of U.S. Hwy 290 near Elgin. Table 4C.13-2 lists the archeological sites within a one-mile corridor of this segment of the project area. The northern pipeline option would impact fifty-seven cultural resource sites. The southern pipeline option would impact 126 sites. Table 4C.13-3 and Table 4C.13-4 list the archeological sites within the northern and southern project areas, respectively. Considering that the owner or controller of the project will likely be a political subdivision of the State of Texas (i.e. river authority, municipality, county, etc.), they will be required to coordinate with the Texas Historical Commission regarding if the project will affect waters of the United States or wetlands, the project sponsor will also be required to coordinate with the U.S. Army Corps of Engineers regarding impacts to cultural resources.

Table 4C.13-2.
Archeological Sites within One-Mile Corridor
of the Project Area between U.S. Hwy 79 and U.S. Hwy 290

41BP332	41LE147	41LE243	41LE298	41MM251	41MM33
41BP335	41LE150	41LE244	41LE300	41MM276	41MM330
41BP603	41LE151	41LE246	41LE303	41MM278	41MM331
41BP617	41LE152	41LE247	41LE304	41MM279	41MM333
41BP630	41LE153	41LE248	41LE305	41MM281	41MM334
41BP631	41LE154	41LE249	41LE306	41MM282	41MM335
41BP632	41LE155	41LE250	41LE54	41MM283	41MM58
41LE108	41LE156	41LE251	41LE55	41MM284	41MM60
41LE109	41LE157	41LE253	41LE56	41MM285	41MM69
41LE112	41LE159	41LE270	41LE57	41MM286	
41LE113	41LE160	41LE274	41LE58	41MM288	
41LE116	41LE161	41LE275	41LE59	41MM305	
41LE121	41LE162	41LE276	41LE60	41MM307	
41LE122	41LE163	41LE277	41MM108	41MM308	
41LE123	41LE164	41LE278	41MM109	41MM309	
41LE133	41LE165	41LE279	41MM145	41MM310	
41LE134	41LE167	41LE286	41MM146	41MM311	
41LE135	41LE194	41LE287	41MM148	41MM312	
41LE137	41LE202	41LE288	41MM149	41MM313	
41LE138	41LE209	41LE289	41MM150	41MM314	
41LE141	41LE227	41LE290	41MM152	41MM315	
41LE142	41LE232	41LE292	41MM153	41MM317	
41LE143	41LE236	41LE293	41MM154	41MM319	
41LE144	41LE239	41LE294	41MM162	41MM322	
41LE145	41LE240	41LE295	41MM216	41MM326	
41LE146	41LE241	41LE296	41MM217	41MM329	

Table 4C.13-3.
Archeological Sites within One-Mile Corridor
of the Northern Pipeline Option

41BP235	41BP365	41BX1320	41GU79
41BP237	41BP366	41BX178	41GU85
41BP238	41BP367	41BX64	41LE111
41BP239	41BP383	41BX772	41LE119
41BP247	41BP384	41BX782	41LE120
41BP248	41BP388	41BX783	41LE149
41BP249	41BP400	41BX784	41LE195
41BP250	41BP474	41CW25	41LE203
41BP260	41BP514	41CW44	41LE254
41BP305	41BP620	41CW9	41MM257
41BP330	41BP68	41CW94	41MM323
41BP331	41BP89	41GU35	41MM325
41BP333	41BX1146	41GU62	
41BP338	41BX1317	41GU77	
41BP343	41BX1318	41GU78	

Table 4C.13-4.
Archeological Sites within One-Mile Corridor
of the Southern Pipeline Option

41BP119	41BP168	41BP246	41BX1099	41BX534	41GZ146
41BP120	41BP169	41BP302	41BX1100	41BX535	41GZ209
41BP121	41BP170	41BP334	41BX1101	41BX541	41GZ24
41BP125	41BP171	41BP336	41BX1104	41BX663	41GZ87
41BP126	41BP172	41BP337	41BX1109	41BX664	41GZ88
41BP130	41BP192	41BP38	41BX1110	41BX665	41GZ89
41BP131	41BP218	41BP432	41BX1111	41BX666	41GZ91
41BP133	41BP219	41BP433	41BX1112	41BX793	41LE192
41BP139	41BP221	41BP527	41BX1113	41BX835	41LE228
41BP141	41BP224	41BP54	41BX1116	41BX842	41LE263
41BP144	41BP225	41BP55	41BX1117	41BX848	41MM140
41BP145	41BP227	41BP948	41BX1118	41BX849	41MM257
41BP149	41BP228	41BP97	41BX1538	41BX850	41MM280
41BP150	41BP230	41BX1055	41BX345	41BX864	41MM287
41BP152	41BP233	41BX1056	41BX439	41BX868	41MM316
41BP153	41BP236	41BX1057	41BX465	41BX870	41WN94
41BP154	41BP240	41BX1058	41BX521	41BX871	41WN95
41BP155	41BP242	41BX1059	41BX527	41BX980	41WN96
41BP156	41BP243	41BX1072	41BX528	41BX989	41WN97
41BP164	41BP244	41BX1073	41BX529	41BX995	41WN98
41BP167	41BP245	41BX1098	41BX532	41GZ129	41WN99

4C.13.4 Engineering and Costing

Groundwater would be developed by constructing conventional, vertical wells, a collector pipeline, pump stations, and terminal storage along a line from south of U.S. Hwy 79 near Rockdale to north of U.S. Hwy 290 near Elgin. From the terminal storage, the water would be pumped through a pipeline to either central Bexar County (northern pipeline option) or to southern Bexar County (southern pipeline option). Common to the two options is the Well Field and Collection System of wells, pipelines, and pump stations and a Transmission System of storage, pipelines, and pump stations to a point south of the Colorado River in Bastrop County. The wells would be constructed to public water supply standards. The major facilities required for these options are:

- Well Field, and Collection and Conveyance System (to U.S. Hwy 290):
  - Wells
  - Pipelines
  - Pump Station

- Transmission System (from U.S. Hwy 290 to Bexar County):
  - Storage
  - Pipeline
  - Pump Station
- Water Treatment Plant
  - Iron and Manganese removal
- Integration to distribution system

The approximate locations of the well fields, pipeline routes, and water treatment plants for the northern and southern options are shown in Figure 4C.13.2 and 4C.13.3, respectively.

Estimates were prepared for capital costs, annual debt service, operation and maintenance, water purchases, power, land, and environmental mitigation. These costs are summarized in Tables 4C.13-2 and 4C.13-3. The annual costs, including debt service for a 30-year loan at 6 percent interest and operation and maintenance costs, including power, are estimated to be $50,245,000 and $53,927,000 for the northern pipeline and southern pipeline options, respectively (Tables 4C.13-5 and 4C.13-6). Depending upon transmission route and terminal treatment location, this water management strategy produces water at estimated costs of $914/acft/yr or $980/acft/yr. The cost estimates include potential fees levied by well field land owners and underground water conservation districts.

Table 4C.13-5.
Cost Estimate for Simsboro Aquifer
Bastrop, Lee, and Milam Counties with Delivery to
Central Bexar County via the Northern Pipeline Route
(Second Quarter 2002 Prices)

Item	***Total Project Costs***
Capital Costs	
Wells (120 wells)	$42,480,000
Well Field Pipelines and Booster Station	$25,399,000
Transmission Pipeline, Pump Stations and Ground Storage (54”, 107-miles)	$224,986,000
Water Treatment Plant (50 MGD, Level 2)	$20,900,000
Distribution System Improvements	$65,023,000
Total Capital Cost	**$378,788,000**
Engineering, Legal and Contingency	$79,691,000
Environmental & Archaeology Studies and Mitigation	$3,508,000
Land Acquisition & Surveying (541 acres, mine property and well fields excluded)	$5,015,000
Groundwater Purchase	$5,640,000
ALCOA Construction Program Management Fee	$5,070,000
Interest During Construction (2 years, 6% int, 4% ret)	$32,609,000
Total Project Cost	**$510,321,000**
Annual Costs	
Debt Service (6% interest, 30 years)	$32,350,000
Operations and Maintenance	$7,010,000
Pumping Energy	$7,303,000
ALCOA Project Management Fees	$300,000
Purchase of Groundwater	$2,000,000
Groundwater District Fees ($0.05/1,000 gal)	$897,000
Mitigation Reserves	$385,000
Total Annual Cost	**$50,245,000**
Available Project Yield (acft/yr)	**55,000**
Annual Cost of Water ($/acft)	**$914**
Annual Cost of Water ($/1,000 gal)	**$2.80**

Notes:
1. Facilities sized for uniform delivery of 55,000 acft/yr
2. Distribution system improvements are regional planning estimates.

Table 4C.13-6.
Cost Estimate for Simsboro Aquifer
Bastrop, Lee, and Milam Counties with Delivery to
Southern Bexar County via the Southern Pipeline Route
(Second Quarter 2002 Prices)

Item	*Total Project Costs*
Capital Costs	
Wells (120 wells)	$42,480,000
Well Field Pipelines and Booster Station	$25,399,000
Transmission Pipeline, Pump Stations and Ground Storage (54", 143-miles)	$251,597,000
Water Treatment Plant (50 MGD, Level 2)	$20,900,000
Distribution System Improvements	$65,023,000
Total Capital Cost	**$340,376,000**
Engineering, Legal and Contingency	$87,901,000
Environmental & Archaeology Studies and Mitigation	$2,032,000
Land Acquisition & Surveying (248 acres, mine property, well field, and shared right-of-way w/ Regional Carrizo for Bexar County Project excluded)	$2,258,000
Groundwater Purchase	$5,640,000
ALCOA Construction Program Management Fee	$5,070,000
Interest During Construction (2 years, 6% int, 4% ret)	$35,056,000
Total Project Cost	**$478,333,000**
Annual Costs	
Debt Service (6% interest, 30 years)	$34,750,000
Operations and Maintenance	$7,343,000
Pumping Energy	$8,252,000
ALCOA Project Management Fees	$300,000
Purchase of Groundwater	$2,000,000
Groundwater District Fees ($0.05/1,000 gal)	$897,000
Mitigation Reserves	$385,000
Total Annual Cost	**$53,927,000**
Available Project Yield (acft/yr)	**55,000**
Annual Cost of Water ($/acft)	**$980**
Annual Cost of Water ($/1000 gal)	**$3.01**

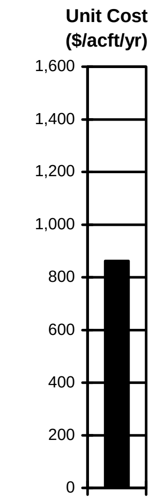
Notes:
1. Facilities sized for uniform delivery of 55,000 acft/yr
2. Distribution system improvements are regional planning estimates.
3. Environmental and archaeology studies and mitigation and land acquisition and surveying costs based on shared right-of-way with Regional Carrizo for Bexar County water management strategy.

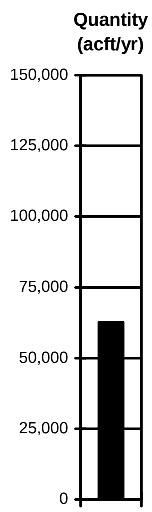
4C.13.5 Implementation Issues

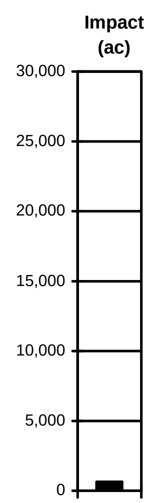
Major issues of the development of groundwater from the Simsboro Aquifer in Bastrop, Lee, and Milam Counties for the South Central Texas Water Planning Region include:

- Possibly additional hydrogeology, and environmental data and analyses of the effects of pumping the aquifer at 55,000 acft/yr for an extended period of time.
- Impact on:
  - Endangered species
  - Water levels in the aquifer
  - Baseflow in streams, and
  - Wetlands
- Regulations of groundwater conservation districts (Lost Pines and Post Oak Savannah).
- Potential groundwater quality degradation from leakage of groundwater through the mine.
- Resistance to movement of water from one river basin to another and from one planning region to another.
- It will be necessary to obtain the following permits or approvals:
  - TCEQ approval for public water wells
  - Lost Pines and Post Oak Savannah Groundwater Districts’ well and production permits
  - USCE Sections 10 and 404 dredge and fill permits for pipelines
  - GLO sand and gravel removal permits
  - GLO easement of use of state-owned land
  - TPWD sand, gravel, and marl permit
- Permitting, at a minimum, will require these studies:
  - Habitat mitigation plan
  - Environmental studies
  - Cultural resource studies and mitigation

2006 South Central Texas Regional Water Plan
Water Management Strategy Summary Sheet







Name: **Regional Carrizo to Bexar County**

Description: Four well fields (42 wells) in Gonzales, Wilson, and Bexar Counties to deliver a total of 62,588 ac-ft/year of Carrizo groundwater to SAWS Twin Oaks facility in southern Bexar County. Approximately 98 miles of raw water pipeline and 37 miles of treated water transmission pipeline, three raw water pump stations, and expansion of water treatment plant at Twin Oaks to accommodate increased demand.

***Decade Needed*:** 2000 – 2010

Cost, Quantity of Water, and Land Impacted

Unit Cost of Water:	**862**	**$/acft/yr**	**Treated Water Delivered**
Quantity of Water:	**62,588**	**acft/yr**	**Reliability = Firm**
Land Impacted:	**675**	**acres**	**Pipeline ROW, wellheads, pump stations**

Additional Considerations per Regional Water Planning Guidelines

Environmental Factors:
Pipeline could traverse endangered or threatened species habitat.

Impacts on Water Resources:
Long-term reduction in aquifer levels could affect discharge from small springs and streamflows in outcrop.

Impacts on Agricultural & Natural Resources:
Long-term reduction in aquifer levels could affect discharge from small springs and streamflows in outcrop.

Other Relevant Factors per SCTRWPG:
Local groundwater conservation districts, in particular Evergreen Underground Water Conservation District (EUWCD) and Gonzales County Underground Water Conservation District (GCUWCD) have rules and management plans that have been considered in project planning. This project was evaluated in conformance with the existing rules of the Gonzales County UWCD. Part of the supply developed by this project exceeds the amount of available water identified in the current Gonzales County UWCD management plan. The amount of water needed by the project that exceeds the available water in the management plan cannot be implemented unless and until permits are received from the Gonzales County UWCD. This project does not cause the Gonzales UWCD management plan to be in conflict with the South Central Texas Regional Water Plan. See Public Comments and SCTRWPG Responses Developed through Facilitation for Issues 2, 5, 6, and 7 in Section 10.2.2.3.

Comparison of Strategies to Meet Needs:
Low to moderate unit cost. Limited conflicts with other recommended water strategies including SSLGC Project Expansion, Wells Ranch Carrizo Project, and/or Hays/Caldwell Carrizo Project. Recent EUWCD rule changes may affect estimated costs.

Interbasin Transfer Issues: Not applicable.

Third-Party Impacts of Voluntary Transfers:
Mitigation (i.e., lowering of pumps, drilling of new wells, etc.) is planned for affected third parties.

Regional Efficiency: New supply proximate to Bexar County.

Water Quality Considerations: Iron and manganese removal may be necessary.

(This page intentionally left blank.)

4C.14 Regional Carrizo-Wilcox Aquifer for Bexar County Supply

4C.14.1 Description of Water Management Strategy

The Carrizo-Wilcox Aquifer is one of four major aquifers in the South Central Texas Water Planning Region. In the Wintergarden area, which is generally considered to be west of the Atascosa-Frio county line, the aquifer has been extensively developed for many decades. In Atascosa County, the aquifer has had limited development; Bastrop, Caldwell, Gonzales, Guadalupe, and Wilson Counties have had very limited aquifer development. Overall, the water quality of the Carrizo-Wilcox Aquifer is suitable for use as a water supply, except for elevated concentrations of iron and manganese in many areas.

Bexar County and other counties along the IH-35 corridor have near-term projected shortages in municipal supply. Several water purveyors in Region L—including SAWS, Schertz-Seguin Local Government Corporation (SSLGC), Bexar Metropolitan Water District (BMWD), and a consortium of interests serving water customers in the Hays/Caldwell area—are evaluating alternative regional projects to export groundwater from the county of origin to demand centers identified in the regional planning process. One of these alternatives, referred to hereafter as the SAWS Gonzales-Carrizo Project, involves the conveyance of raw groundwater pumped from proposed well fields in Gonzales, Wilson, and Bexar Counties to southern Bexar County for treatment and delivery to SAWS' distribution system. This project is described in this section. Other proposed regional Carrizo Aquifer projects, including the SSLGC well field expansion, the Wells Ranch Project, and the Hays/Caldwell Carrizo Project (Figure 4C.14-1), are detailed in Sections 4C.15, 4C.16, and 4C.17, respectively

SAWS is moving forward with plans to significantly expand their water supply capabilities as water demands are projected to exceed currently available supplies during this decade. One of the major new projects that SAWS is developing is the Gonzales-Carrizo Project. The SAWS Gonzales-Carrizo Project is planned in Wilson and Gonzales Counties, which are represented by separate groundwater conservation districts. The Evergreen Underground Water Conservation District (EUWCD) includes Atascosa, Frio, Karnes, and Wilson Counties and the Gonzales County Underground Water Conservation District (GCUWCD) includes most of Gonzales County (Section 3.1). Each district has developed rules and regulations that affect the export of groundwater and implementation of any project must comply with these rules.

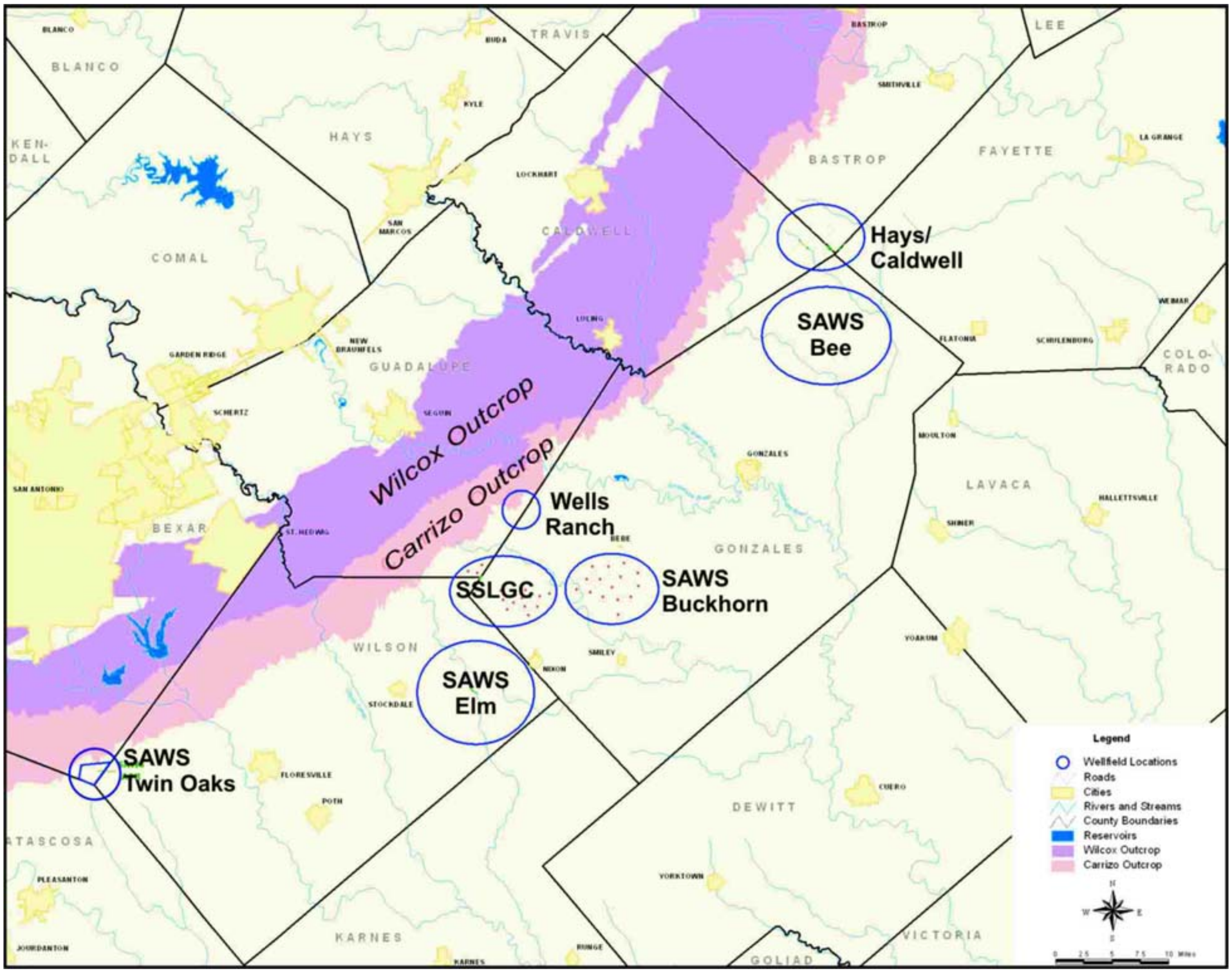


Figure 4C.14-1. Proposed Regional Carrizo Aquifer Projects

This report presents a preferred conceptual plan, cost estimates, and an implementation plan. Under this strategy, the development of a 62,600 acft/yr supply of Carrizo-Wilcox Aquifer groundwater from four well fields (Figure 4C.14-2) was evaluated for municipal and industrial demands in San Antonio, the major municipal demand center of the South Central Texas Region. The evaluation included: (1) identifying suitable areas for large municipal well fields and developing a conceptual project plan, (2) computing the water level drawdown in the vicinity of the well fields using both the state-sponsored groundwater availability models for the southern Carrizo-Wilcox/Queen City-Sparta Aquifers (SCWQSGAM)[1] and the South Central Carrizo

[1] Intera, with Bureau of Economic Geology and R.J. Brandes Company, "Groundwater Availability Models for the Queen city and Sparta Aquifers", Prepared for the Texas Water Development Board, October 2004.

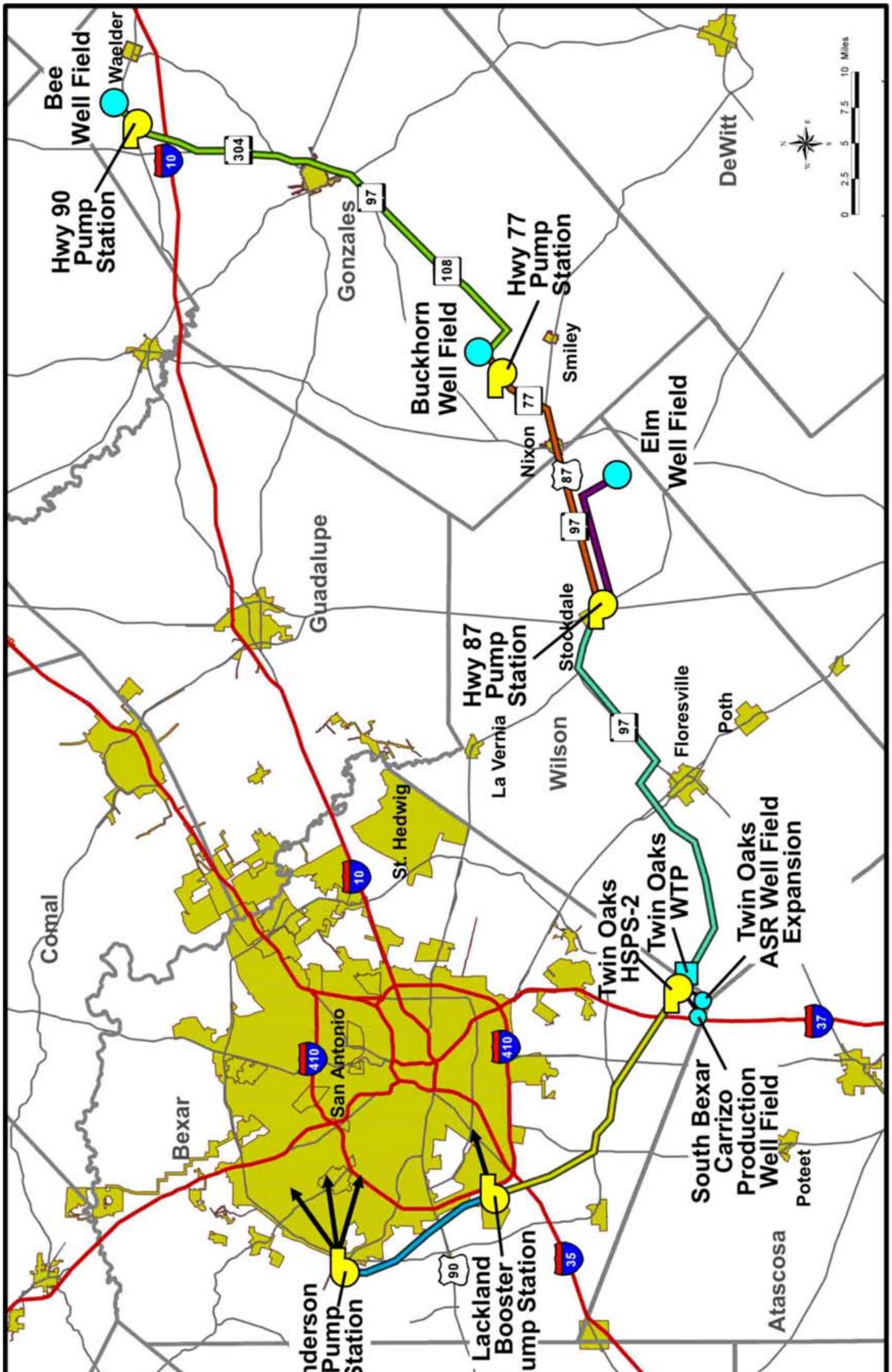


Figure 4C.14-2. SAWS Gonzales-Carrizo Project Location Map

System (SCCS)[2] groundwater model, (3) computing the effects on streamflow in the Guadalupe and San Antonio Rivers, and (4) estimating costs for project implementation.

The conceptual plans are based on projected water demands for SAWS and estimated potential production from the proposed well field areas. The project is divided into three phases. In the initial phase, the Buckhorn Well Field in southwestern Gonzales County will be constructed to produce about 22,600 acft/yr of water from the Carrizo Aquifer, and the South Bexar Well Field will be constructed to produce 6,400 acft/yr by 2008. Subsequently, the Elm Well Field in eastern Wilson County will be constructed to produce 11,000 acft/yr by 2010. Finally, the Bee Well Field in northeastern Gonzales County will be constructed to produce 22,600 acft/yr by 2013. Total production capacity results in approximately 62,600 acft/yr from the four well fields in Bexar, Gonzales, and Wilson Counties (Figure 4C.14-2). A raw water pipeline will convey groundwater across Gonzales and Wilson Counties to SAWS Twin Oaks Water Treatment Plant (WTP), which will be upgraded to meet increased supply. A treated water pipeline will deliver the water from the WTP to integration points on the west side of San Antonio. A summary of anticipated project facilities is presented in Table 4C.14-1.

Table 4C.14-1.
Summary of Project Facilities

Facility	***Preferred Plan***
Production Wells	42
Well Field Collection Piping	65 miles
Pump Stations	5
Storage Reservoirs (above ground)	27 million gallons
Raw Water Transmission Pipelines	98 miles
Treated Water Transmission Pipelines	37 miles
Twin Oaks Water Treatment Plant	60 MGD
Maximum Diameter of Treated Water Pipeline	60 inches

Water from the Gonzales-Carrizo well fields will be delivered at a uniform rate of 50.2 MGD to an expanded Twin Oaks WTP in south Bexar County where it will be treated. Bexar-Carrizo groundwater would be pumped to the WTP at a maximum rate of 10.0 MGD. For

[2] HDR Engineering Inc., "South Central Carrizo System Groundwater Model, SAWS Gonzales Carrizo Project," San Antonio Water System, November 2004.

the conceptual plan, the combined Gonzales-Carrizo and Bexar-Carrizo water supplies will be treated and pumped to the west side of San Antonio.

4C.14.2 Available Yield and Projected Drawdown

A review of existing reports,3,4,5 the extent of other groundwater users in the area, and local hydrogeologic data gathered by SAWS and SSLGC indicates that well fields can be developed in a section of the Carrizo-Wilcox Aquifer that extends from northeastern Wilson County to northeastern Gonzales County.

Large capacity wells in the area typically produce in excess of 1,000 gallons per minute. The conceptual plan developed by SAWS indicates that 15 wells would be would be required in the Buckhorn Well Field, 6 wells in the South Bexar Well Field, 6 wells in the Elm Well Field, and 15 wells in the Bee Well Field, for a total of 42 production wells. Well spacing in Gonzales County is planned to be about 1 mile, in compliance with GCUWCD rules regulating production and spacing. Well spacing in Wilson County has not yet been determined.

4C.14.2.1 Drawdown

To estimate the effects of the projected pumpage to meet local demands and the various projected pumpage for groundwater export through the year 2060, two groundwater models were used. As mandated by SB1 rules, the TWDB-sponsored SCWQSGAM for the southern Carrizo-Wilcox and Queen City-Sparta was used to simulate drawdown associated with various water management strategies. In addition, SAWS sponsored the use of the SCCS groundwater model, developed by HDR Engineering for SAWS, to conduct additional simulations. The SCCS and SCWQSGAM have a significant area of overlap; however, the SCWQSGAM extends southwest all the way to the Rio Grande, while the SCCS is centered on Wilson and Gonzales Counties (Figure 4C.14-3).

Four predictive simulations were conducted to individually estimate drawdown associated with baseline pumpage for local supply and each of the proposed export projects. These simulations are outlined below and pumpage associated with export projects is presented

[3] Klemt, W.B., et al., "Ground-Water Resources of the Carrizo Aquifer in the Winter Garden Area of Texas," Texas Water Development Board (TWDB) Report 210, Vols. 1 and 2, 1976.
[4] HDR Engineering, Inc (HDR) and LBG-Guyton Associates (LBG), "Interaction Between Ground Water and Surface Water in the Carrizo-Wilcox Aquifer," TWDB, August 1998.
[5] Ryder, P.D. and Ardis, A.F., "Hydrology of the Texas Gulf Coast Aquifer System," U.S. Geological Survey Open-File Report 91-64, 1991.

in Figure 4C.14-4 and Table 4C.14-2. Estimated pumpage quantities for the export projects were obtained in cooperation with representatives of SAWS, SSLGC, BMWD, and CRWA during or soon after a coordination meeting held October 13, 2004 in the City of Seguin.

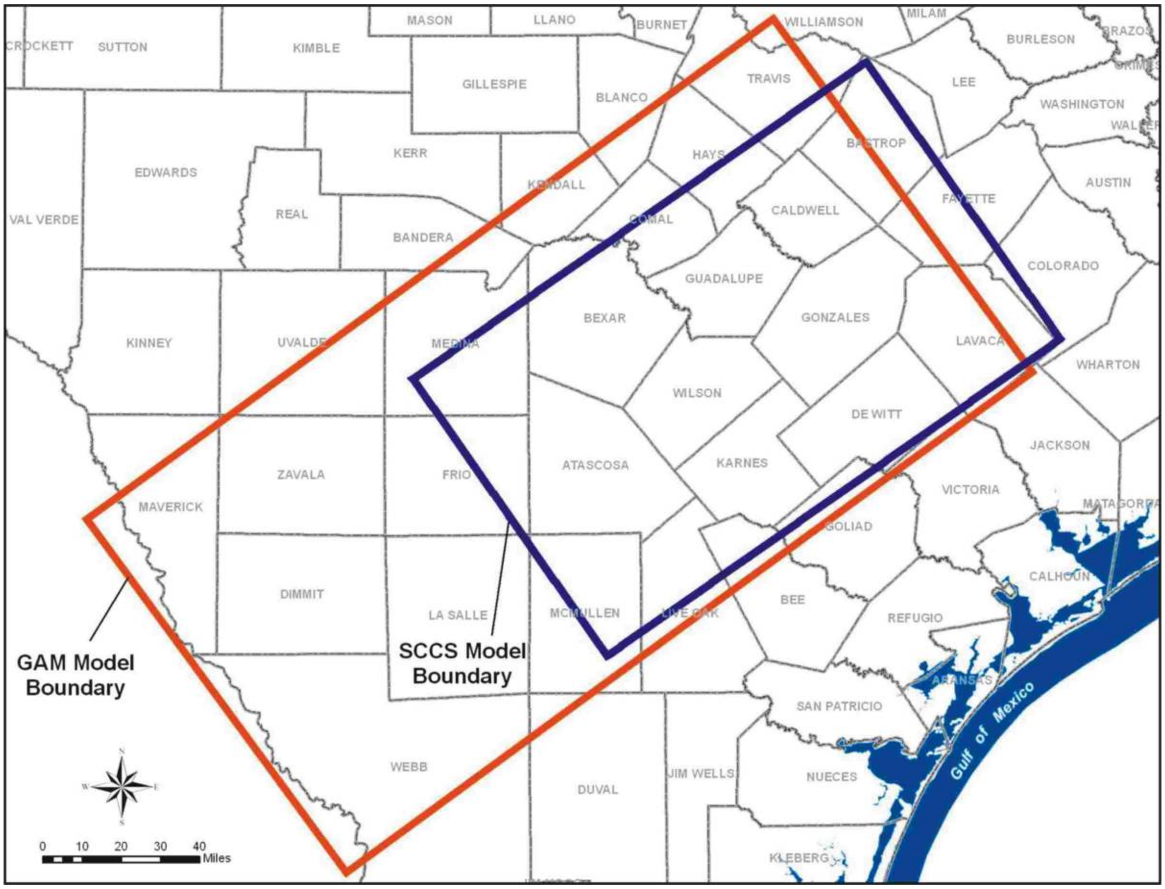


Figure 4C.14-3. SCCS and SCWQSGAM Model Boundaries

- Baseline Local Supply Pumpage: Only groundwater pumpage for local use associated with each water user group as described in Section 4C.12 was included. Region L demand projections for each user group were reviewed, and any demand associated with a groundwater source from the subject aquifers was included in the well pumpage dataset. Half of livestock demands were assigned to groundwater.
- Baseline + SSLGC: SSLGC planned pumpage of 25,000 acft/yr by 2020 was added on top of the baseline pumpage.
- Baseline + SSLGC + SAWS: SAWS pumpage as previously described was added on top of the SSLGC and baseline pumpage.
- All Projects: This simulation added pumpage for the Wells Ranch Project at 9,000 acft/yr by 2010 and pumpage for the Hays/Caldwell Interests Project beginning in 2030 and increasing to 27,000 acft/yr by 2060.

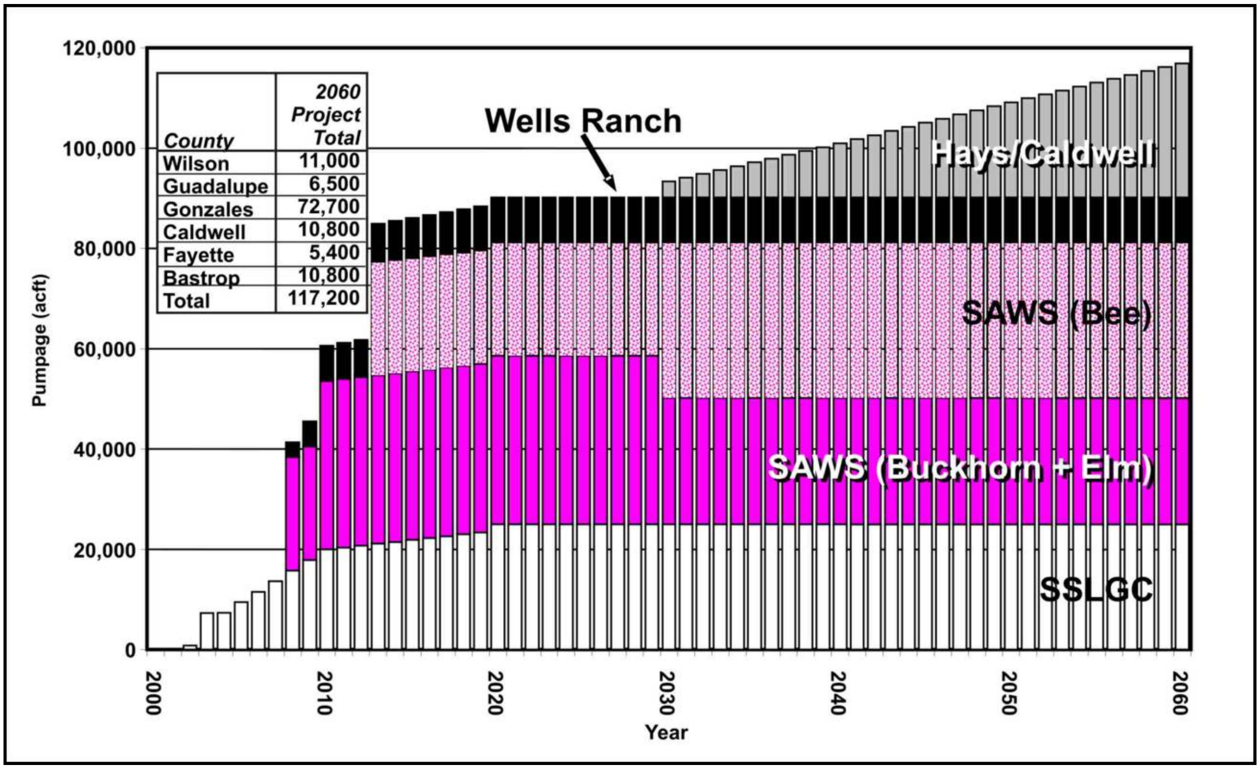


Figure 4C.14-4. Carrizo Groundwater WMS Predictive Pumpage

Table 4C.14-2.
Carrizo Groundwater WMS Predictive Pumpage

Year	*SSLGC*	*SAWS Buckhorn*	*SAWS Elm*	*SAWS Bee*	*Wells Ranch*	*Hays/ Caldwell*	*Total*
2002	796	0	0	0	0	0	796
2008	11,794	22,600	0	0	3,000	0	37,394
2010	20,000	22,600	11,000	0	7,000	0	60,600
2013	21,500	22,600	11,000	22,600	7,600	0	85,300
2020	25,000	22,600	11,000	22,600	9,000	0	90,200
2030	25,000	16,950	8,250	31,000	9,000	3,168	93,368
2040	25,000	16,950	8,250	31,000	9,000	10,757	100,957
2050	25,000	16,950	8,250	31,000	9,000	18,981	109,181
2060	25,000	16,950	8,250	31,000	9,000	27,000	117,200

To show the long-term change in water level, maps were produced showing total drawdown (with all pumpage included), drawdown attributed to the SAWS Gonzales-Carrizo Project, and water level hydrographs at locations near the proposed well fields.

Total drawdown for Baseline+SSLGC+SAWS pumpage using both the SCCS Model and the SCWQSGAM are presented in Figures 4C.14-5 and 4C.14-6. The SCWQSGAM results show more drawdown (170 feet) than the SCCS (130 feet) over the combined SSLGC/Buckhorn pumping center. However, in the Bee Well Field, the SCWQSGAM results show less drawdown (130 feet) than the SCCS Model (150 feet).

Drawdown attributed to the SAWS project was calculated by subtracting the modeled Baseline+SSLGC water elevations from the Baseline+SSLGC+SAWS elevations. The resulting values are drawdown attributed to the SAWS Gonzales-Carrizo Project. The SCCS-calculated drawdown attributed to SAWS estimates 80 feet over the Buckhorn Well Field and 140 feet over the Bee Well Field (Figure 4C.14-7). The SCWQSGAM-calculated drawdown attributed to SAWS estimates 90 feet over the Buckhorn Well Field and 100 feet over the Bee Well Field (Figure 4C.14-8). Again, the SCWQSGAM predicts more drawdown than the SCCS Model over the Buckhorn Well Field, but less than the SCCS Model over the Bee Well Field.

In order to display the effects of pumpage on drawdown through time, monitor well hydrographs were generated for communities near the project area, including Stockdale, Nixon, Smiley, and Bebe, as well as a GCUWCD monitor well located near the proposed Bee Well Field (GCMW-17). Predictive hydrographs calculated by the SCCS Model are presented in Figure 4C.14-9, and hydrographs generated by the SCWQSGAM are presented in Figure 4C.14-10. Both models indicate that combined drawdown resulting from all projects will not exceed 100 feet at the monitoring well locations within 5 years of SAWS' startup.

The combined effects of the development of Regional Carrizo groundwater are of importance at several locations on the Guadalupe and San Antonio Rivers. Drawdowns in groundwater levels in the aquifer outcrops may result in reduced flow from the aquifers to the streams. For comparative purposes, the model-calculated surface water/groundwater interaction at four streams (San Antonio River and modeled tributaries, Cibolo Creek, Guadalupe River, and San Marcos River and modeled tributaries) within the model outcrop area in the Guadalupe-San Antonio River Basin are computed using both the SCCS model and the SCWQSGAM.

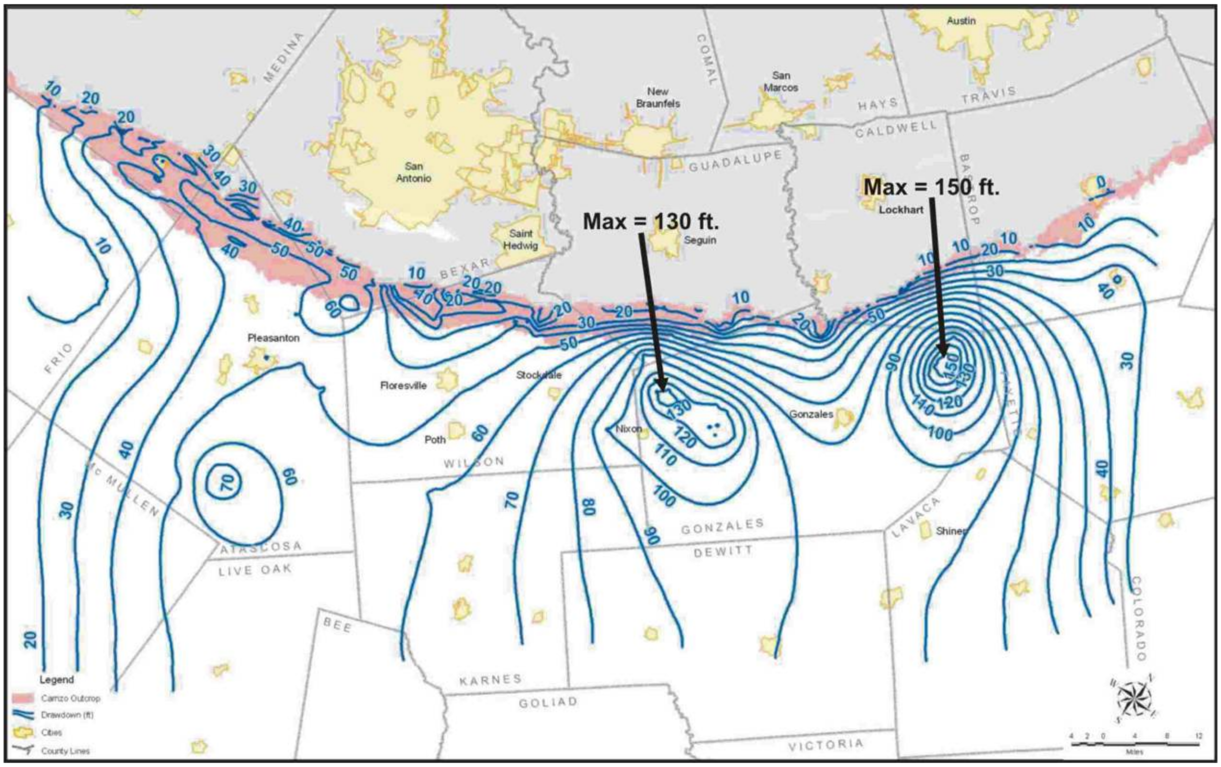


Figure 4C.14-5. SCCS Model Results (Baseline+SSLGC+SAWS)

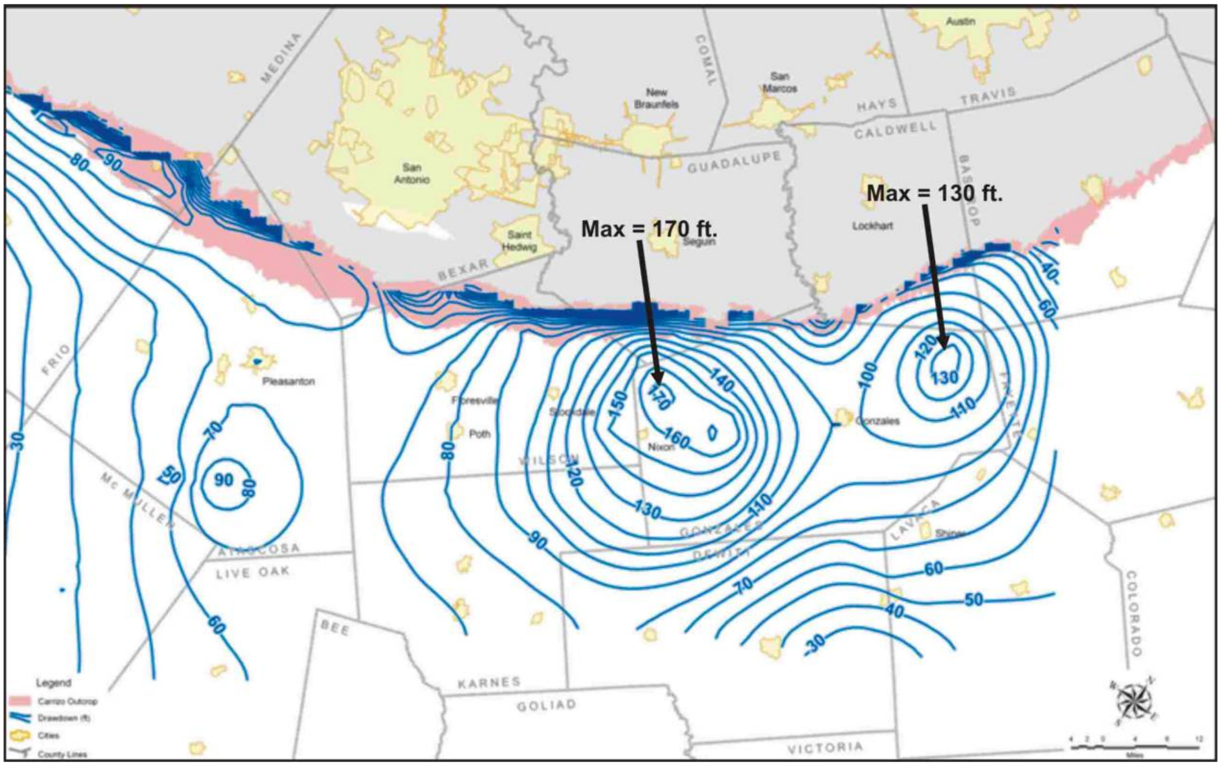


Figure 4C.14-6. SCWQSGAM Model Results (Baseline+SSLGC+SAWS)

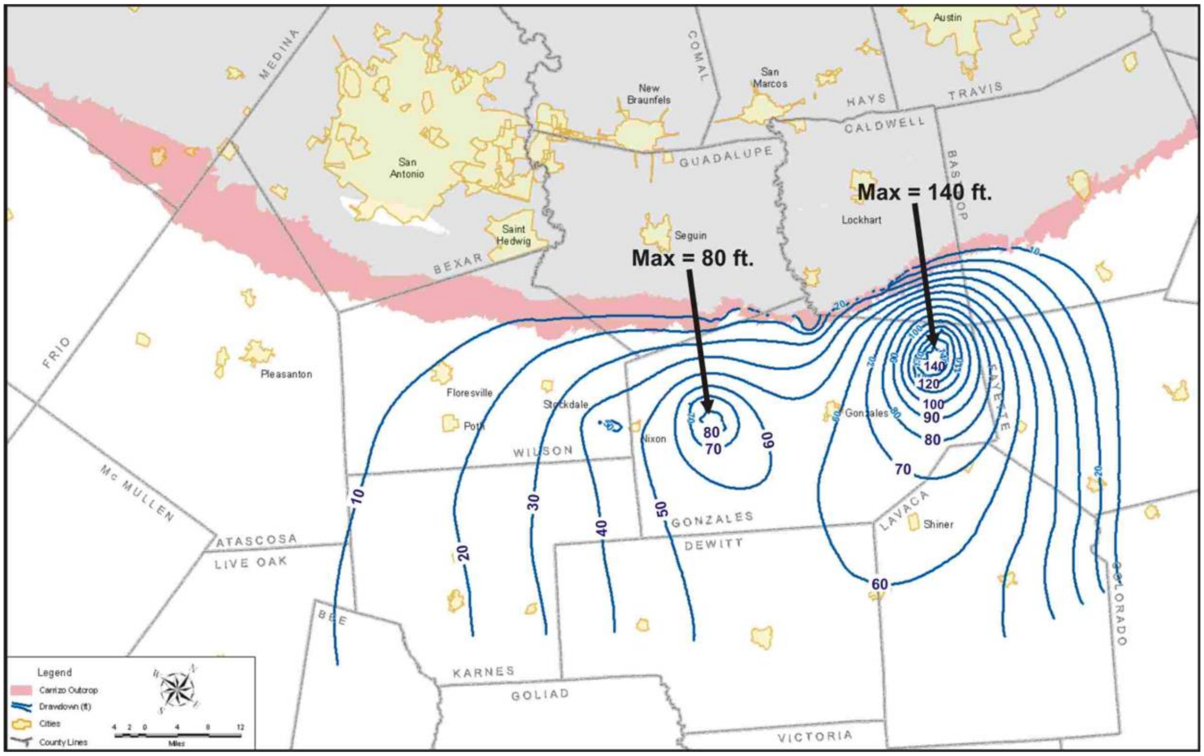


Figure 4C.14-7. SCCS Model Results (2002-2060 Drawdown Attributable to the SAWS Gonzales-Carrizo Project)

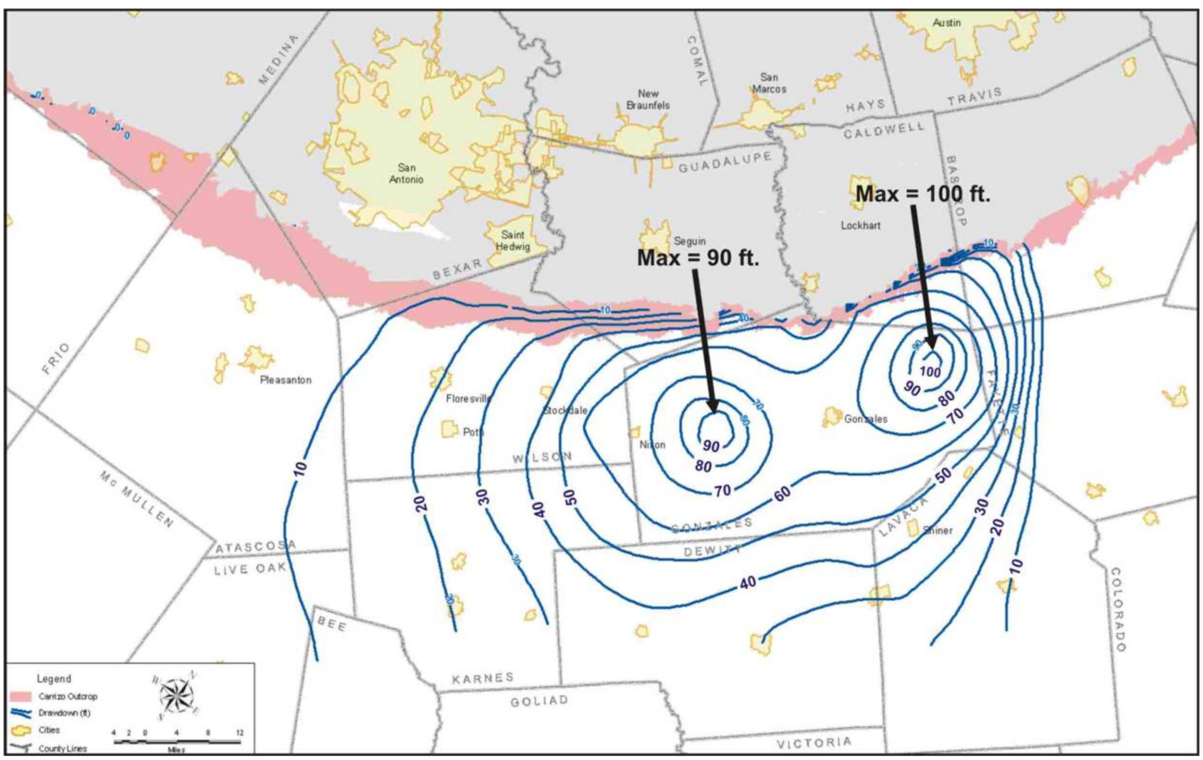


Figure 4C.14-8. SCWQSGAM Results (2002-2060 Drawdown Attributable to the SAWS Gonzales-Carrizo Project)

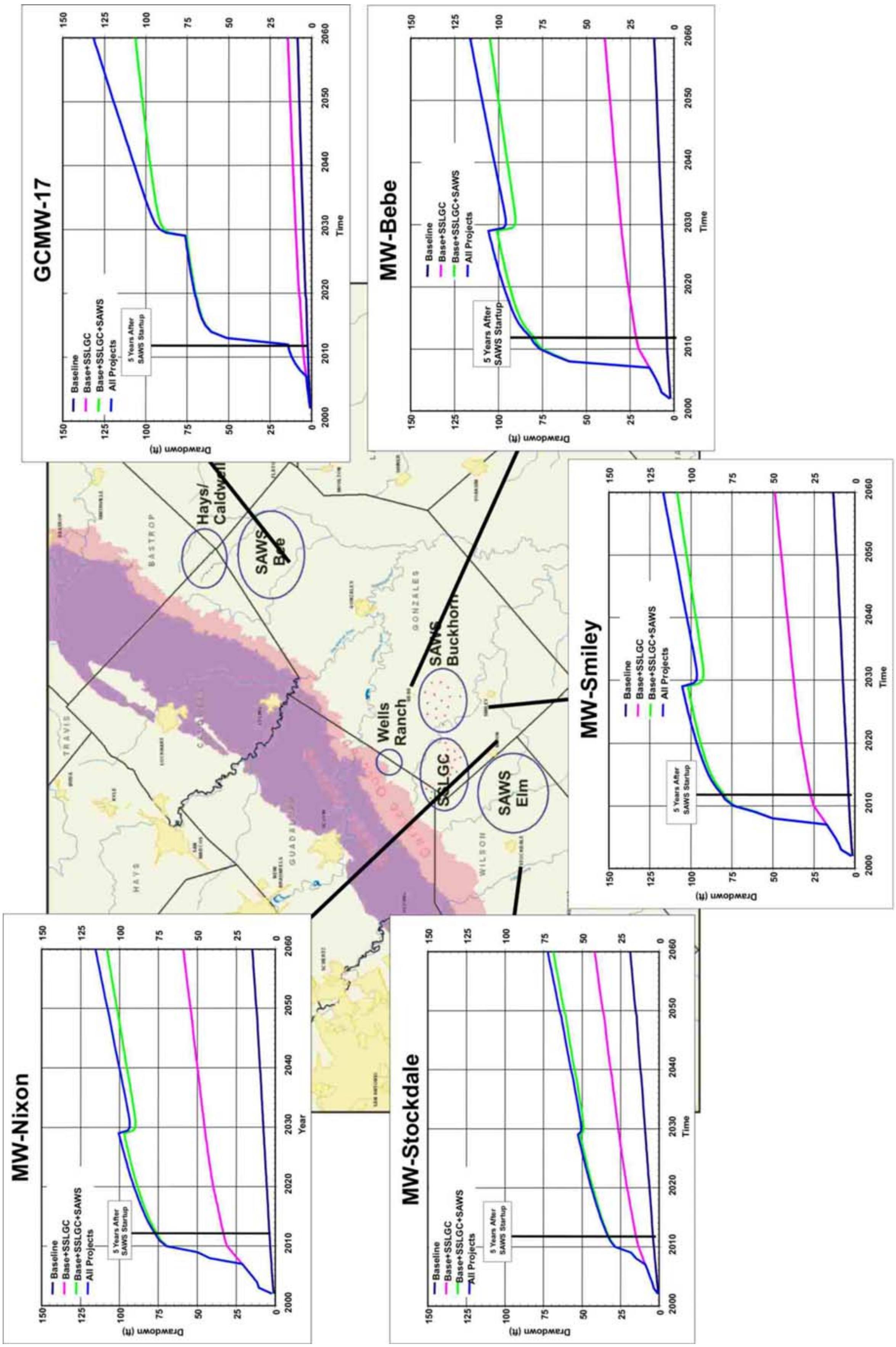


Figure 4C.14-9. SCCS Predictive Drawdown Hydrographs

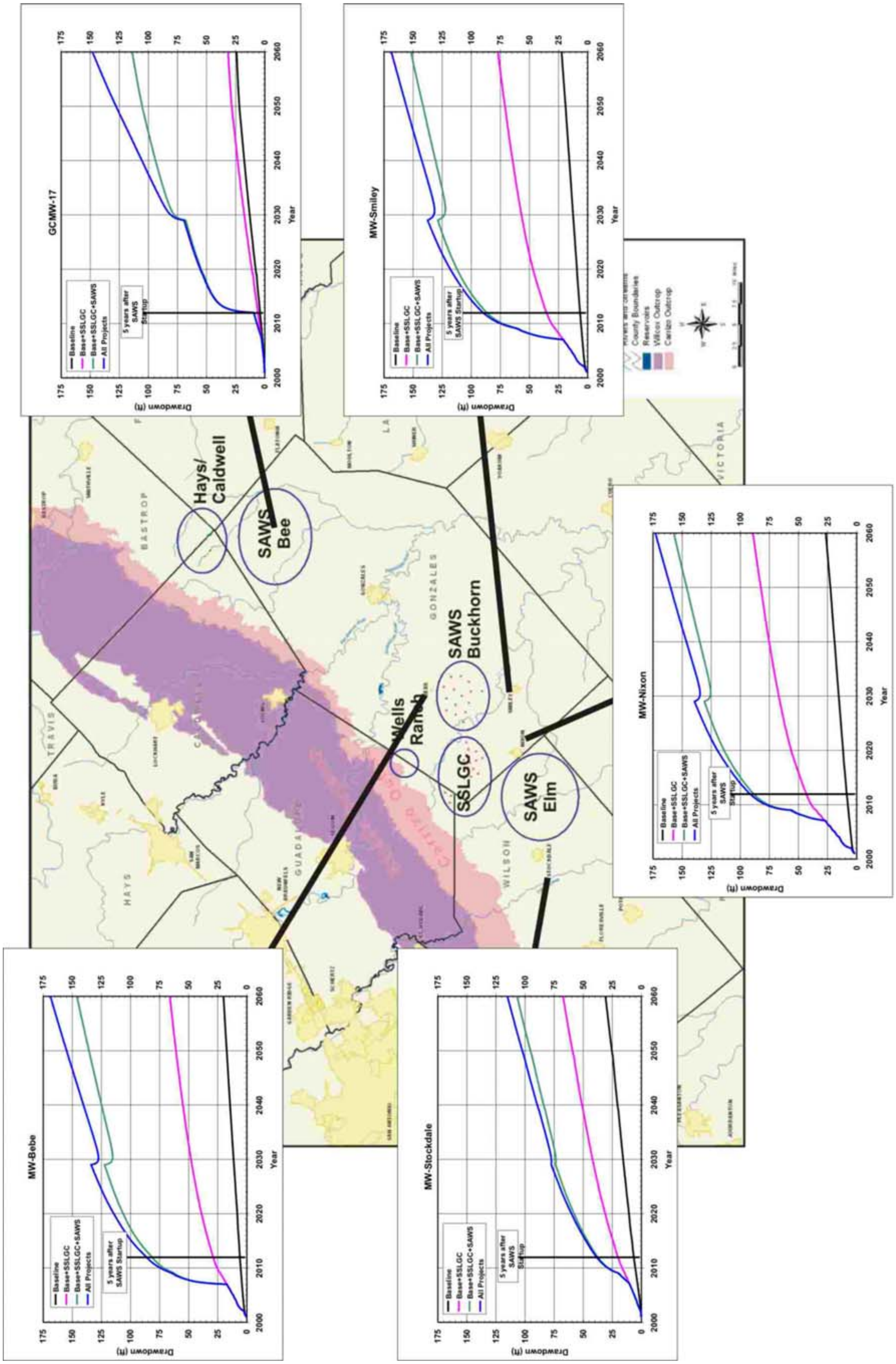


Figure 4C.14-10. GAM Predictive Drawdown Hydrographs

In order to estimate these effects, model-reported flux between all the modeled aquifers (i.e., Carrizo, Wilcox, Queen City, and Sparta) and the streams was evaluated after each of the four predictive scenarios was completed. Calculated flux in 2002 (the first year of the simulation), was compared with flux in 2060 under each of the four pumpage scenarios (local supply, local + SSLGC, local + SSLGC + SAWS, local + all projects). By this method, the incremental contribution of each component of pumpage to the total reduction in surface water flux can be separated. For example, Figure 4C.14-11 displays the stream flux results for Cibolo Creek under each predictive scenario using the SCCS model. With pumpage for local supply and all export projects pumping through 2060, the SCCS calculates a reduction in flow from the aquifers to Cibolo Creek from 7.0 cfs to 0.6 cfs, a total reduction of 6.4 cfs. Of this total, 4.2 cfs, or 66% of the total reduction, is attributed to pumpage for local supply. A surface water flux reduction of 1.3 cfs (20% of total) is attributed to the SSLGC project. A further surface water flux reduction of 0.8 cfs (12% of total) is attributed to the SAWS Gonzales project. The remainder of the flux change is attributed to the Wells Ranch and Hays/Caldwell projects. Tables 4C.14-3 and 4C.14-4 present the results for predictive surface water/groundwater flux for the two models in the subject streams. For the scenario of local groundwater supply plus all

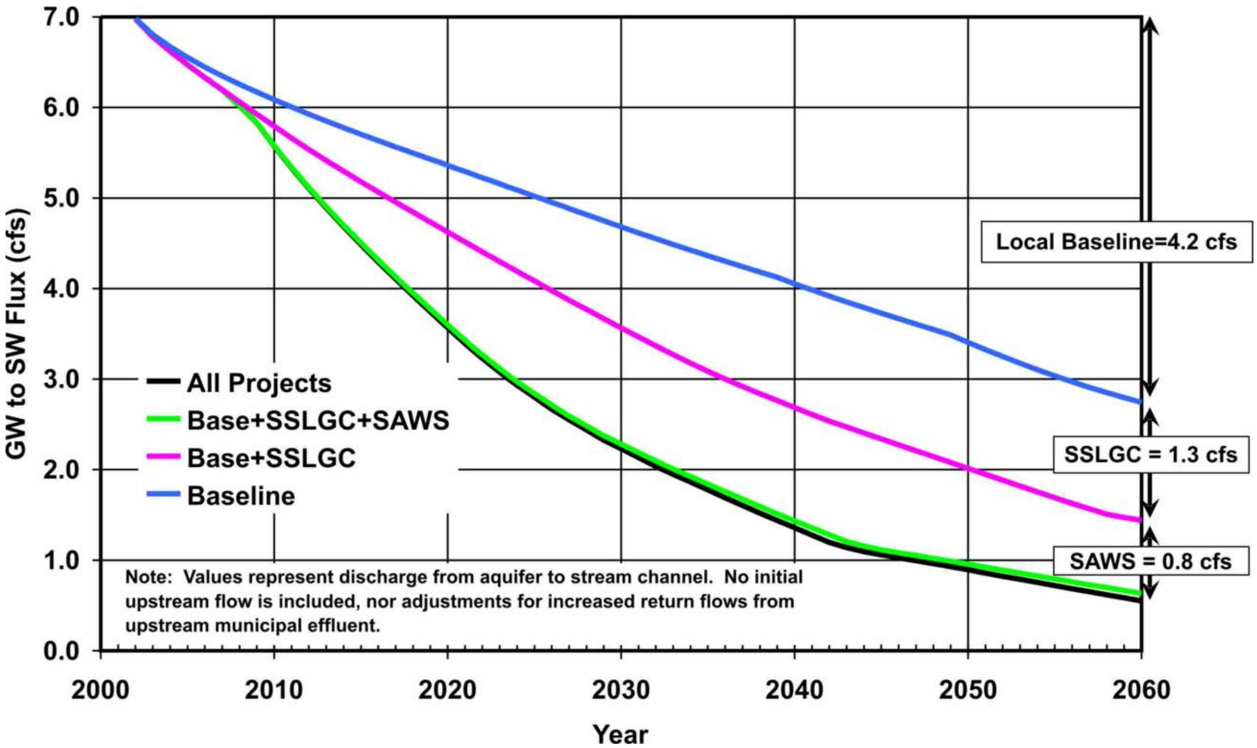


Figure 4C.14-11. Region L Water Management Strategies Evaluation Simulations SCCS 2002 – 2060 Cibolo Creek SW/GW Interaction

Table 4C.14-3.
SCWQSGAM Groundwater Model
Predictive Surface Water/Groundwater Interaction

Stream	2002 Flux (cfs)	Local Supply	Local + SSLGC	Local + SSLGC + SAWS	Local + All Projects	Net Change Max Pumpage (cfs)
		2060 Flux (cfs)				
San Antonio River and Tributaries	-4.7	-13.8	-14.9	-15.6	-15.7	-11.0
Cibolo Creek	5.6	1.8	1.3	0.7	0.7	-5.0
Guadalupe River	2.5	2.6	1.3	-0.2	-0.6	-3.1
San Marcos River and Tributaries	25.7	17.8	14.0	6.7	6.4	-19.3

Notes:

Negative flux values indicate that stream is losing flow to the aquifer at the indicated rate.

Positive values indicate that aquifers are discharging to the stream.

Table 4C.14-4.
SCCS Groundwater Model Predictive
Surface Water/Groundwater Interaction

Stream	2002 Flux (cfs)	Local Supply	Local + SSLGC	Local + SSLGC + SAWS	Local + All Projects	Net Change Max Pumpage (cfs)
		2060 Flux (cfs)				
San Antonio River and Tributaries	12.6	1.7	1.1	0.2	0.2	-12.5
Cibolo Creek	7.0	2.7	1.4	0.6	0.5	-6.4
Guadalupe River	6.3	5.4	4.3	1.8	1.1	-5.3
San Marcos River and Tributaries	17.0	12.9	12.1	8.0	7.2	-9.8

Note:

Positive flux values indicate stream reach is gaining flow from aquifer.

export projects, the San Antonio River system is calculated to undergo a reduction in flow of 11.0 cfs according to the SCWQSGAM, and a reduction of 12.5 cfs according to the SCCS model. Cibolo Creek is calculated to undergo a flow reduction of 5.0 cfs by the SCWQSGAM, and a reduction of 6.4 cfs by the SCCS model. The Guadalupe River is calculated to have a flow reduction of 3.1 cfs by the SCWQSGAM, and a reduction of 5.3 cfs by the SCCS model. The San Marcos River system is calculated to have a flow reduction of 19.3 cfs by the SCWQSGAM, and a reduction of 9.8 cfs by the SCCS model. One important distinction between the results of the two models is that the SCWQSGAM simulates the San Antonio River as losing water to the aquifers throughout the predictive simulation period. In the SCCS model, although some individual cells within the San Antonio stream segments lose water to the aquifer, it remains a net gaining stream over all four aquifers crossed in the model. Similarly, the SCWQSGAM simulates the Guadalupe River as changing from net gaining to net losing as a result of the predictive pumpage, but the SCCS model simulates the Guadalupe as remaining net gaining throughout the predictive simulation period.

At the direction of the SCTRWPG, the results from the Carrizo groundwater simulations using the SCCS model were used to estimate the cumulative effects at several locations in these rivers by using the GSA WAM[6] for baseline and full development scenarios. As was done in the 2001 Regional Water Plan to evaluate the impact of specified pumpage scenarios on surface water flows in the Guadalupe-San Antonio River Basin, changes in streamflows were extracted from the groundwater model runs and incorporated into the GSA WAM as adjustments to streamflow. Results based on pumpage consistent with projected needs are reported in Section 7.1 (Volume I) and Section 4C.18, “Cumulative Effects of Carrizo Aquifer Development Strategies.”

4C.14.3 Environmental Issues

The development of a well field in western Gonzales County and the construction of a pipeline to deliver raw water to a terminus in Bexar County will potentially involve several regulatory approvals that have environmental and cultural resource components. As a subdivision of the State, SAWS’ easements are considered public lands, and SAWS is charged

[6] HDR, “Water Availability in the Guadalupe-San Antonio River Basin,” Texas Natural Resources Conservation Commission, December 1999.

with protecting the historic, cultural, and environmental resources of the State of Texas. The determination of locations of environmental and cultural resources (such as the potential presence of protected species, waters of the United States, adjacent wetlands and cultural resources) will assist SAWS in selecting facility locations and construction procedures that can minimize potential delays, and reduce mitigation liabilities. This report section discusses the potential impacts to environmental and cultural resources known to exist along the proposed pipeline route.

The project area includes land primarily in the South Texas Plains vegetational area, with the eastern end of the proposed pipeline and well field entering into the edges of the Blackland Prairies vegetational area.[7] The landforms of the project area are typically nearly level to gently rolling and are slightly-to-moderately dissected by streams which are tributaries of the San Antonio and Guadalupe Rivers. The original vegetation was a brushy chaparral-grassland with dense thickets of oaks and mesquites on the ridges and oak, pecan and ash common along streams. Continued grazing and cessation of fires altered the vegetation to such a degree that the region south of San Antonio is now commonly called the Texas Brush Country.[8] Thorny brush is the predominant vegetation type in the region, including mesquite (*Prosopis pubescens*) acacia (*Acacia greggii*), prickly pear (*Opuntia spp.)* and mimosa, among others. Many of the vegetational elements common to the Brush Country are seen in the western half of the proposed pipeline. The vegetation of Wilson and Gonzales Counties is now primarily composed of rangeland and crops and post-oak woodlands. Common woody species include mesquite (*Prosopis glandulosa*), live oak (*Quercus virginiana*), post oak (*Quercus stellata*), acacia (*Acacia sp.*), brazil (*Zizyphus obovata*), spiny hackberry (*Celtis pallida*), whitebrush (*Aloysia gratissima*), lime pricklyash (*Zanthoxylum fagara*), Texas persimmon (*Diospyros texana*), shrubby blue sage (*Salvia ballotiflora*) and lotebush (*Zizyphus obtusifolia*). Grasses of the area commonly include little bluestem (*Schizachyrium scoparium*), indiangrass (*Sorghastrum nutans*) and switchgrass (*Panicum virgatum*). Pricklypear (*Opuntia sp.*) is common throughout most of the area.[9]

The eastern end of the proposed pipeline and well field are located in the Blackland Prairies vegetational area in Gonzales County. This rolling and well-dissected vegetational area

---

[7] Gould, F.W., "The Grasses of Texas," Texas A&M University Press, College Station, Texas, 1975.
8 Inglis, J.M., "A History of Vegetation on the Rio Grande Plain," Project W-84-R-Texas, Bulletin No. 45, Texas Parks and Wildlife Department. Austin, Texas, 1964.
[9] Hatch, S.L., K.N. Gandhi, and L. E. Brown, "Checklist of the Vascular Plants of Texas," Texas Agricultural Experiment Station, Texas A & M University, College Station, 1990.

was historically a luxuriant tallgrass prairie dominated by little bluestem, big bluestem (*Andropogon gerardii*), indiangrass, and dropseeds (*Sporobolus sp.*). During the turn of the 20th century, about 98 percent of the Blackland Prairie was cultivated for crops. Livestock production has increased dramatically since the 1950s and now only 50 percent of the area is used for cropland. Grazing pressure has increased grass species such as sideoats grama (*Bouteloua curtipendula*), hairy grama (*B. hirsuta*), Mead's sedge (*Carex meadii*), Texas wintergrass (*Stipa leucotricha*) and buffalograss (*Buchloe dactyloides*). Common woody species include mesquite, huisache (*Acacia smallii*), oak (*Quercus sp.*) and elm (*Ulmus sp.*). Oak, elm, cottonwood (*Populus sp.*) and native pecan (*Carya*) are common along drainages.

Vertebrate fauna typifying these regions include the opossum, raccoon, weasel, skunk, white-tailed deer and bobcat as well as a wide variety of amphibians, reptiles and birds. The coyote and javelina are also common to the area, but are found mainly in brush/shrub areas while the red and gray fox are more common in woodlands.[10]

Plant and animal species listed by the USFWS and TPWD as endangered, threatened or rare in the project area are presented in Table 4C.14-5. All endangered, threatened and rare species identified on the TPWD Annotated County Lists of Rare Species for Bexar, Wilson and Gonzales Counties have been included in Table 4C.14-5.

The endangered golden-cheeked warbler (*Dendroica chrysoparia*) and black-capped vireo (*Vireo atricapillus*) may have habitat within the study area. The golden-cheeked warbler inhabits mature oak-Ashe juniper woods for nesting. It requires strips of Ashe juniper bark for nest material. The black-capped vireo nests in dense underbrush in semi-open woodlands having distinct upper and lower stories. It should be noted that the range of the golden-cheek warbler and black-capped vireo only extend into northern and western Bexar County and not the other counties in this project area.

Along the pipeline route, several species listed as threatened by the state may possibly be affected. These include the Cagle's Map Turtle (Graptemys caglei), Indigo Snake (*Drymarchon corais erebennus),* Texas Horned Lizard (*Phrynosoma cornutum),* Texas Tortoise (*Gopherus berlandieri),* and Timber/Canebrake Rattlesnake (*Crotalus horridus).* Cagle's map Turtle is known to inhabit the Guadalupe River segment located to the northeast of the pipeline route and

[10] Jones, J.K. et al., "Annotated Checklist of Recent Land Mammals of Texas," Occasional Papers of the Museum OP-119, Texas Tech University, 1988.

Table 4C.14-5.
Rare and Protected Species in the Project Area

Common Name	Scientific Name	*Impact Value*	*Multiplier Based on Status*	*Adjusted Impact*	*Summary of Habitat Preference*	*Listing Entity*		*Potential Occurrence in County*
						USFWS[1]	*TPWD*[1]	
American Peregrine Falcon	*Falco peregrinus anatum*	0	3	0	Open country; cliffs	DL	E	Nesting/Migrant
Arctic Peregrine Falcon	*Falco peregrinus tundrius*	0	2	0	Open country; cliffs	DL	T	Nesting/Migrant
Bald Eagle	*Haliaeetus leucocephalus*	0	2	0	Large bodies of water with nearby resting sites	LT-PDL	T	Nesting/Migrant
Big Red Sage	*Salvia penstemonoides*	1	1	1	Endemic; Creekbeds and seepage slopes of limestone canyons			Resident
Black Bear	*Usus americanus*	0	2	0	Mountains, broken country, woods, brushlands, forests	T/SA; NL	T	Resident
Black-capped Vireo	*Vireo atricapillus*	2	3	6	Semi-open broad-leaved shrublands	LE	E	Nesting/Migrant
Black-spotted Newt	*Notophthalmus meridionalis*	1	2	2	Wet or temporally wet arroyos, canals, ditches, shallow depressions; aestivates underground during dry periods		T	Resident
Blue Sucker	*Cycleptus elongatus*	0	2	0	Channels and flowing pools with exposed bedrock		T	Resident
Bracted Twistflower	*Streptanthus bracteatus*	1	1	1	Endemic; Shallow clay soils over limestone; rocky slopes			Resident
Braken Bat Cave Meshweaver	*Cicurina venii*	0	3	0	Small eyeless spider, in Karst features in western Bexar County.	LE		Resident
Cagle's Map Turtle	*Graptemys caglei*	3	2	6	Waters of the Guadalupe River Basin	C1	T	Resident
Cave Myotis Bat	*Myotis velifer*	0	1	0	Colonial & cave dwelling; hibernates in limestone caves of Edwards Plateau			Resident
Cokendolpher Cave Harvestman	*Texella cokendolpheri*	0	3	0	Small eyeless harvestman, karst features in north-central Bexar county.	LE		Resident
Comal Blind Salamander	*Eurycea tridentifera*	0	2	0	Endemic; Semi-troglobitic; Springs and waters of caves		T	Resident
Correll's False Dragon-Head	*Physostegia correllii*	1	1	1	Wet soils			Resident

Table 4C.14-5 (Continued)

Edwards Plateau Spring Salamander	*Eurycea sp. 7*	0	1	0	Troglobitic; Edwards Plateau			Resident
Elmendorf's Onion	*Allium elmendorfii*	3	1	3	Endemic; deep sands derived from Queen City and similar Eocene formations			Resident
Golden-Cheeked Warbler	*Dendroica chrysoparia*	0	3	0	Woodlands with oaks and old juniper	LE	E	Nesting/Migrant
Government Canyon Bat Cave Meshweaver	*Cicurina vespera*	0	3	0	Small, eyeless spider, karst features in northwestern Bexar County.	LE		Resident
Government Canyon Bat Cave Spider	*Neoleptoneta microps*	0	3	0	Small, eyeless or essentially eyeless spider; karst features in N and NW Bexar Co.	LE		Resident
Ground Beetle #1	*Rhadine exilis*	0	3	0	Eyeless beetle, karst features in northern Bexar County.	LE		Resident
Ground Beetle #2	*Rhadine infernalis*	0	3	0	Small eyeless ground beetle; karst features in northern and western Bexar County.	LE		Resident
Guadalupe Bass	*Micropterus treculi*	2	1	2	Streams of eastern Edwards Plateau			Resident
Guadalupe Darter	*Percina sciera apristis*	2	1	2	Raceways of medium streams and rivers.			
Helotes Mold Beetle	*Bastrisodes venyivi*	0	3	0	Small, essentially eyeless mold beetle; karst features in N and NW Bexar Co.	LE		Resident
Henslow's Sparrow	*Ammodramus henslowii*	1	1	1	Weedy fields or cut over areas; bare ground for running and walking			Nesting/Migrant
Indigo Snake	*Drymarchon corais erebennus*	1	2	2	Grass prairies and sand hills; usually thornbush woodland and mesquite savannah of coastal plain		T	Resident
Jaguarundi	*Felis yagouaroudi*	0	3	0	South Texas thick brushlands, favors areas near water	LE	E	Resident
Keeled Earless Lizard	*Holbrookia propinqua*	0	1	0	Coastal dunes, Barrier islands and sandy areas			Resident
Manfreda Giant-Skipper	*Stallingsia maculosus*	1	1	1	Larvae feed inside leaf shelter and pupae found in cocoon made of leaves fastened by silk			Resident
Madla's Cave Spider	*Cicurina madla*	0	3	0	Small, eyeless or essentially eyeless spider; karst features in N and NW Bexar Co.	LE		Resident
Mimic Cavesnail	*Phreatodrobia imitata*	0	1	0	Subaquatic; wells in Edwards Aquifer			Resident

Table 4C.14-5 (Continued)

Mountain Plover	*Charadrius montanus*	0	1	0	Shortgrass plains and fields, sandy deserts, plowed fields			Nesting/Migrant
Ocelot	*Felis pardalis*	0	3	0	Dense chaparral thickets; mesquite-thorn scrub and live oak mottes; avoids open areas	LE	E	Resident
Palmetto Pill Snail	*Euchemotrema leai cheatumi*	0	1	0	Terrestrial snail from Palmetto State Park.			Resident
Parks' Jointweed	*Polygonella parksii*	1	1	1	South Texas Plains; subherbaceous annual in deep loose sands, spring-summer			Resident
Plains Spotted Skunk	*Spilogale putorius interrupta*	0	1	0	Catholic; Wooded, brushy areas and tallgrass prairies			Resident
Robber Baron Cave Spider	*Cicurina baronia*	0	3	0	Small, eyeless or essentially eyeless spider; karst features in N and NW Bexar Co.	LE		Resident
Sandhill Woolywhite	*Hymenopappus carrizoanus*	3	1	3	Endemic; Open areas in deep sands derived from Carrizo and similar Eocene formations			Resident
Spot-tailed Earless Lizard	*Holbrookia lacerata*	1	1	1	Oak-juniper woodlands and mesquite-prickly pear			Resident
Texas Garter Snake	*Thamnophis sirtalis annectens*	1	1	1	Varied, especially wet areas; bottomlands and pastures			Resident
Texas Horned Lizard	*Phrynosoma cornutum*	1	2	2	Varied, sparsely vegetated uplands		T	Resident
Texas Salamander	*Eurycea neotenes*	0	1	0	Endemic, from springs, seeps and caves.			Resident
Texas Tortoise	*Gopherus berlandieri*	2	2	4	Open brush with grass understory; open grass and bare ground avoided; occupies shallow depressions at base of bush or cactus, underground burrows, under objects; active March-Nov		T	Resident
Timber/Canebrake Rattlesnake	*Crotalus horridus*	1	2	2	Bottomland hardwoods		T	Resident
Toothless Blindcat	*Trogloglanis pattersoni*	0	1	0	Fish.		T	Resident
Whooping Crane	*Grus americana*	0	3	0	Potential migrant	LE	E	Migrant
White-faced Ibis	*Plegadis chihi*	0	2	0	Prefers freshwater marshes.		T	
Widemouth Blindcat	*Satan eurystomus*	0	1	0	Fish		T	Resident

Table 4C.14-5 (Continued)

Wood Stork	*Buteo americana*	0	2	0	Prairie ponds, flooded pastures or fields; shallow standing water		T	Nesting/Migrant
Zone-tailed Hawk	*Buteo albonotatus*	0	2	0	Arid, open country including deciduous or pine-oak woodland; nests in various habitats and sites		T	Nesting/Migrant

[1]***Texas Parks and Wildlife Department (TPWD), Unpublished 2005, March 2005, Data and Map Files of the Wildlife Science Research and Diversity Division maintained by TPWD, Austin, Texas.***

* LE/LT=Federally Listed Endangered/Threatened E/SA, T/SA=Federally Listed Endangered/Threatened by Similarity of Appearance
C1=Federal Candidate for Listing DL, PDL=Federally Delisted/Proposed for Delisting NL=not Federally Listed E, T=State Listed Endangered/Threatened
PE, PT=Federally Proposed Endangered/ Threatened Blank = Rare, but no regulatory listing status

well field and the San Marcos River in Palmetto State Park. These species and others, which are endemic to the Edwards Plateau region, could only be affected by the delivery pipeline and not the well field.

The Texas Biological and Conservation Data System (TXBCD) system files identify several plant species of concern on or in the vicinity of the pipeline route. The only species listed to occur directly on the alternative pipeline route is the Elmendorf's onion (*Allium elmendorfii*) and Sandhill Woolywhite (Hymenopappus carrizoanus). Three occurrences of Elmendorf's onion are identified on pipeline alternatives west of the San Antonio River in addition to two occurrences of Sandhill Woolywhite. Other plant species of concern, which have known occurrences within a mile of the pipeline route, include Parks Jointweed (*Polygonella parksii*), Big Red Sage (Salvia penstemonoides), Texas Tauschia (*Tauschia texana*), and Crown Coreopsis (*Coreopsis nuecensis*). Both Elmendorf's onion and Parks' jointweed are found in deep sands. The big red sage usually grows along creek beds and seepage slopes of limestone canyons. These species of concern are considered to be rare, but are not protected by USFWS or TPWD.

Waters of the U.S. crossings along the pipeline corridor consist primarily of the riverine habitats of Picosa, Mariana, Sequine Branch, Marcelinas, Cibilo, Clifton Branch, Ecleto, Clear Fork, O'Neal, Yow, Cottonwood and Sandies Creeks and the San Antonio and Guadalupe Rivers and their tributaries, as well as associated palustrine habitats that are generally composed of narrow bands of wetlands adjacent to these watercourses. Although the USFWS National Wetlands Inventory (NWI) maps identify both temporary and permanent palustrine wetlands adjacent to the pipeline corridors, and well fields, a ground survey wetland delineation will be required to determine which of these and other features would be affected and to what extent. The wetland delineation will document the locations of streambeds, stream widths, quality and type of water bodies, types of aquatic vegetation, presence of special aquatic resources (such as wetlands) and area of jurisdictional Waters of the U.S. likely to be disturbed during construction. Unclassified intermittent streams are typically unnamed upper headwater and pasture drainages while classified streambeds are typically larger, well-defined bodies of water such as the San Antonio River and Cibolo Creek. Perennial streams are of greatest concern, and therefore should be considered for a boring/tunneling approach. Perennial streams crossed by the pipeline route include the San Antonio River, Cibolo Creek, Clear Fork Creek, Sandies Creek and O'Neal

Creek. A wetland delineation must be conducted on the pipeline easement, well pads, access roads and other areas to be disturbed during construction.

Based on the review of available records housed at the Texas Archeological Research Laboratory in Austin, the following sites appear to occur within 1 mile of the proposed pipeline (Table 4C.14-6).

Most of the proposed well field areas and pipeline route have not been subjected to systematic archeological survey. Therefore, the available information on site occurrence is incomplete. An archeological survey of the project area should be undertaken to more accurately determine actual impacts to cultural resources. The issuance of a 404 permit for the project constitutes a federal action under 36 CFR 800. In this context, federal agencies must consider impacts to cultural resources within their jurisdiction that are either listed, or eligible for listing, on the National Register of Historic Places prior to permit approval. In addition, SAWS is considered a political subdivision of the State of Texas and derives its powers from the State Constitution, therefore SAWS must also comply with the Antiquities Code of Texas. The Antiquities Code considers all sites, whether known or unknown, on land owned or controlled by a political subdivision, as State Archeological Landmarks, which may not be altered, damaged, or destroyed without a state permit. The procedure for complying with these regulations involves consultation with the USCOE and the THC. It is likely that these agencies will require that the selected pipeline route and the improvements associated with the development of the well fields (e.g., access roads) all undergo an archeological survey to identify potential impacts to cultural resources. Once potential impacts are identified, these agencies may require that the affected sites be avoided or the impacts be mitigated by data recovery or other means.

The project activities which entail regulatory liability result from temporary and permanent disturbance to soils, Waters of the U.S., wetlands, protected species and habitats and cultural resources during construction of well pads, access roads, pipelines and other facilities; permanent conversion of existing habitats or land uses to maintained pipeline rights-of-way; potential disturbance of minor acreages for water treatment facilities, storage stations and well facilities. Indirect effects of construction may include mitigation areas converted to alternate uses to compensate for losses of terrestrial and wetland habitat. The field reconnaissance revealed that the proposed project area does not appear to impact areas likely to be utilized by state or federally protected species.

Table 4C.14-6.
Previously Recorded Sites within 1-Mile Corridor of the Proposed Regional Carrizo for Bexar County Pipeline

Sites	BX848	BX867	BX515	BX1071
	BX850	BX869	BX697	GZ186
	BX849	BX527	BX568	GZ193
	BX851	BX529	BX465	GZ88
	BX853	BX863	BX1083	GZ87
	BX842	BX865	BX1082	GZ91
	BX836	BX866	BX1081	GZ89
	BX520	BX986	BX1084	GZ90
	BX521	BX543	BX1085	GZ154
	BX541	BX670	BX1086	GZ24
	BX536	BX554	BX1102	GZ209
	BX1537	BX862	BX1103	GZ129
	BX1463	BX861	BX1106	BX1079
	BX872	BX864	BX1105	BX1080
	BX345	BX987	BX1208	BX1094
	BX870	BX859	BX1070	BX1097
	BX868	BX519	BX1077	BX1095
	BX528	BX838	BX1114	BX1149

Pre-construction notification and a permit will be required by the USCOE Fort Worth District prior to construction activities. For projects that are expected to have minimal adverse impact on the aquatic environment, and that meet specific conditions, the USCOE has numerous Regional General and Nationwide Permits that are designed to expeditiously process applications for specific projects. A Nationwide Permit or a Regional General Permit for utility lines intake and outfall structures is available for projects such as this. These permits allow discharges of dredged or fill material into non-tidal waters of the United States, excluding non-tidal wetlands adjacent to tidal waters, for the construction, maintenance, or repair of utility lines and associated features that are necessary for the use and maintenance of the structures. Such activities would be authorized, provided the activities meet all of the criteria. USCOE permit conditions will require open-cut stream crossings to return the bed and banks to their pre-construction contours and implement adequate measures to control erosion and accomplish revegetation. There may also be a requirement to preserve and replace topsoil to facilitate revegetation in certain areas, such as wetlands, where vegetation is disturbed. Directional drilling methods may be appropriate for consideration for the pipeline crossings of large classified streams such as the San Antonio River and Cibolo Creek to avoid mitigation liabilities.

If the USCOE District Engineer determines that a proposed project does not qualify for a Regional or Nationwide General Permit, an individual permit would be required. This process currently takes from 6 months to 1 year and the primary determinant of the schedule will be the satisfaction of other regulatory agencies. The specific nature and area of disturbance to jurisdictional Waters of the U.S. for the SAWS Gonzales-Carrizo Project is not possible to determine without the completion of a detailed wetland delineation.

4C.14.4 Engineering and Costing

Groundwater would be developed by constructing four well fields and associated conveyance and storage facilities in a section of the Carrizo-Wilcox Aquifer that extends from southern Bexar County to eastern Wilson County to eastern Gonzales County, as presented in Figure 4C.14-2. The pipeline route traverses about 98 miles from the Bee Well Field to the Twin Oaks Water Treatment Plant. Approximately 37 miles of treated water pipeline convey the water to the west side of San Antonio.

The South Bexar, Elm, Buckhorn, and Bee segments are designed to supply 6,400, 11,000, 22,600, and 22,600 acft/yr, respectively. The major facilities required for these options are:

- Water Collection and Conveyance System
  - Wells
  - Pipelines
  - Pump Station
  - Transmission System
- Storage
- Pipeline
- Pump Stations
- Water Treatment Plant (Upgrade of Existing Plant).

The approximate locations of these facilities were shown in Figure 4C.14-2.

Cost estimates were computed in a detailed concept study produced for SAWS in June 2004 using local and project-specific information for capital and project expenses, annual debt service, operation and maintenance, power, land, and environmental mitigation. In some cases the method of calculating costs differed from the default methodology (Appendix A). For example, the cost estimate for integration into the distribution system is higher using the SAWS estimate than using the default methodology, but contingency percentages applied were lower in the SAWS estimate than the default method. However, because greater detail was involved in the development of the SAWS estimate than is included in the default methodology, the cost estimate developed for the SAWS concept report was converted to Second Quarter 2002 dollars using the CCI index. These costs are summarized in Table 4C.14-7. The costs are estimated for the annual costs, including debt service for a 30-year loan at 6 percent interest and operation and maintenance costs, including power. The cost of water is estimated to be $862 per acft/yr.

4C.14.5 Implementation Issues

Implementation of the Regional Carrizo to Bexar County water management strategy could involve limited conflicts with other water supply options under consideration, including SSLGC project expansion, Wells Ranch Carrizo project, and/or Hays/Caldwell Carrizo project since each of these will be operating all or in part in common groundwater conservation districts.

This project was evaluated in conformance with the existing rules of the Gonzales County UWCD. Part of the supply developed by this project exceeds the amount of available water identified in the current Gonzales County UWCD management plan. The amount of water needed by the project that exceeds the available water in the management plan cannot be implemented unless and until permits are received from the Gonzales County UWCD. This project does not cause the Gonzales UWCD management plan to be in conflict with the South Central Texas Regional Water Plan. See Public Comments and SCTRWPG Response Developed through Facilitation for Issue Number 6 in Section 10.2.2.3.

The development of groundwater in the Carrizo-Wilcox Aquifer in the South Texas Water Planning Region must address several issues. Major issues include:

- Detailed feasibility evaluation including test drilling and aquifer and water quality testing, followed with more detailed groundwater modeling to confirm results of this preliminary evaluation. This has been accomplished for the Buckhorn Well Field.
- Impacts on:
  - Endangered and threatened species,
  - Water levels in the aquifer,
  - Baseflow in streams, and
  - Wetlands.
- Competition with others in the area for groundwater.
- Regulations by the EUWCD and GCUWCD, including the renewal of pumping permits at 5-year intervals in the EUWCD.

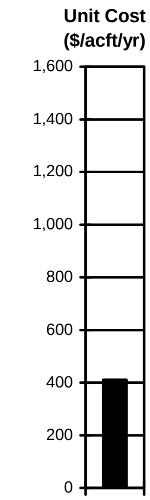
- Water levels did not completely stabilize during the 59-year simulation and if all pumpage continues at 100 percent of project plans, water levels could continue to decrease for some time before stabilizing.

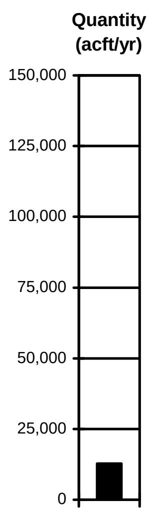
Table 4C.14-7.
Cost Estimate Summary[1]
Regional Carrizo to Bexar County – SAWS Gonzales-Carrizo Project

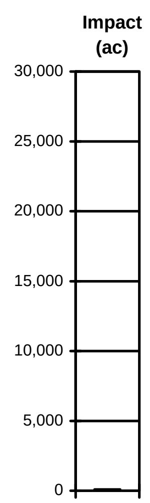
Item	*Estimated Costs for Facilities*
Capital Costs	
Wells	$39,992,000
Well Field Piping	$25,514,000
Pipeline	$95,208,000
Pump Station	$14,831,000
Water Treatment Plant Expansion and Upgrades	$21,198,000
SCADA and Telemetry (Supply)	$2,138,000
Electric Power Infrastructure Improvements (Supply)	$2,672,000
Contingency and Inflation (Supply) (18 percent)	$36,281,000
Integration/Distribution	$83,145,000
Total Capital Costs	**$320,979,000**
Project Costs	
Engineering, Legal, and Program Management (19 percent)	$60,991,000
Environmental & Archaeology Studies, Mitigation, and Permitting	$4,877,000
Land Acquisition and Surveying	$9,731,000
Groundwater Lease Acquisition	$6,176,000
Interest During Construction (3 years, 6 percent interest, 3 percent return)	$57,880,000
Mitigation Reserve for Possible Impacts to Local Wells	$12,002,000
Test Drilling Programs and Concept Studies	$13,958,000
Total Project Cost	**$486,604,000**
Annual Costs	
Debt Service (6 percent interest, 30 years)	$35,354,000
Groundwater Leases	$3,532,000
District Export Fee ($0.025 per 1,000 gal)	$463,000
Maintenance - Pipelines, Tanks, Wells	$2,092,000
Maintenance - Pump Stations, SCADA	$759,000
O & M Water Treatment Plant	$3,870,000
Power (Pumping)	$7,898,000
Total Annual Cost	**$53,968,000**
Available Project Yield (acft/yr)	**62,588**
Annual Cost of Water ($ per acft)	**$862**
Annual Cost of Water ($ per 1,000 gallons)	**$2.65**

[1] Costs based on detailed cost estimate prepared for SAWS using 2004 dollars, adjusted to Second Quarter 2002 dollars using CCI ratio.

2006 South Central Texas Regional Water Plan
Water Management Strategy Summary Sheet







Name: **Regional Carrizo for SSLGC Project Expansion**

Description: The Schertz-Seguin Local Government Corporation (SSLGC) currently operates eight Carrizo Aquifer wells in Gonzales County, which are permitted for a total of 12,200 acft/yr. This strategy involves installing seven additional wells in Gonzales and Guadalupe Counties to pump an additional 12,800 acft/yr, ultimately pumping a total of 25,000 acft/yr from the Carrizo Aquifer. Conveyance facilities are in place and have the capacity to accommodate increased demand. Water treatment facilities (disinfection and iron/manganese removal) need to be expanded to accommodate the increased demand.

***Decade Needed*:** 2000-2010

Cost, Quantity of Water, and Land Impacted

Unit Cost of Water:	**411**	**$/acft/yr**	**Treated Water Delivered**
Quantity of Water:	**12,800**	**acft/yr**	**Reliability = Firm**
Land Impacted:	**8**	**acres**	**Wellheads, access roads.**

Additional Considerations per Regional Water Planning Guidelines

Environmental Factors:

Pipeline could traverse endangered or threatened species habitat.

Impacts on Water Resources:

Long-term reduction in aquifer levels could affect discharge from small springs and streamflows in outcrop.

Impacts on Agricultural & Natural Resources:

Long-term reduction in aquifer levels could affect discharge from small springs and streamflows in outcrop.

Other Relevant Factors per SCTRWPG:

This project was evaluated in conformance with the existing rules of the Gonzales County UWCD. Part of the supply developed by this project exceeds the amount of available water identified in the current Gonzales County UWCD management plan. The amount of water needed by the project that exceeds the available water in the management plan cannot be implemented unless and until permits are received from the Gonzales County UWCD. This project does not cause the Gonzales UWCD management plan to be in conflict with the South Central Texas Regional Water Plan. See Public Comments and SCTRWPG Responses Developed through Facilitation for Issues 2, 5, and 6 in Section 10.2.2.3.

Comparison of Strategies to Meet Needs:

Low unit cost, since much of the necessary infrastructure is in place. Potential conflicts with other recommended water strategies including Regional Carrizo for Bexar County Supply, Wells Ranch Carrizo Project, and/or Hays/Caldwell Carrizo Project.

Interbasin Transfer Issues: Not applicable.

Third-Party Impacts of Voluntary Transfers:

Mitigation (i.e., lowering of pumps, drilling of new wells, etc.) is required by GCUWCD rules for affected third parties.

Regional Efficiency: New supply proximate to existing transmission facilities.

Water Quality Considerations: Iron and manganese removal necessary.

4C.15 Regional Carrizo for SSLGC Project Expansion

4C.15.1 Description of Water Management Strategy

The Schertz-Seguin Water Supply Project, owned and operated by Schertz-Seguin Local Government Corp (SSLGC), currently holds permits to pump 12,200 acft/yr of groundwater from Gonzales County from the Carrizo Aquifer in Western Gonzales County. The primary recipients of the water are the cities of Schertz and Seguin. In addition, the SSLGC has recently signed contracts to supply 400 acft/yr of peaking water to each of the cities of Selma and Universal City. The project presently consists of eight 1,000-gpm Carrizo wells in Western Gonzales County. Figure 4C.15-1 illustrates the existing Schertz-Seguin Water Supply Project system. SSLGC plans to construct additional wells to increase the capacity of their system.

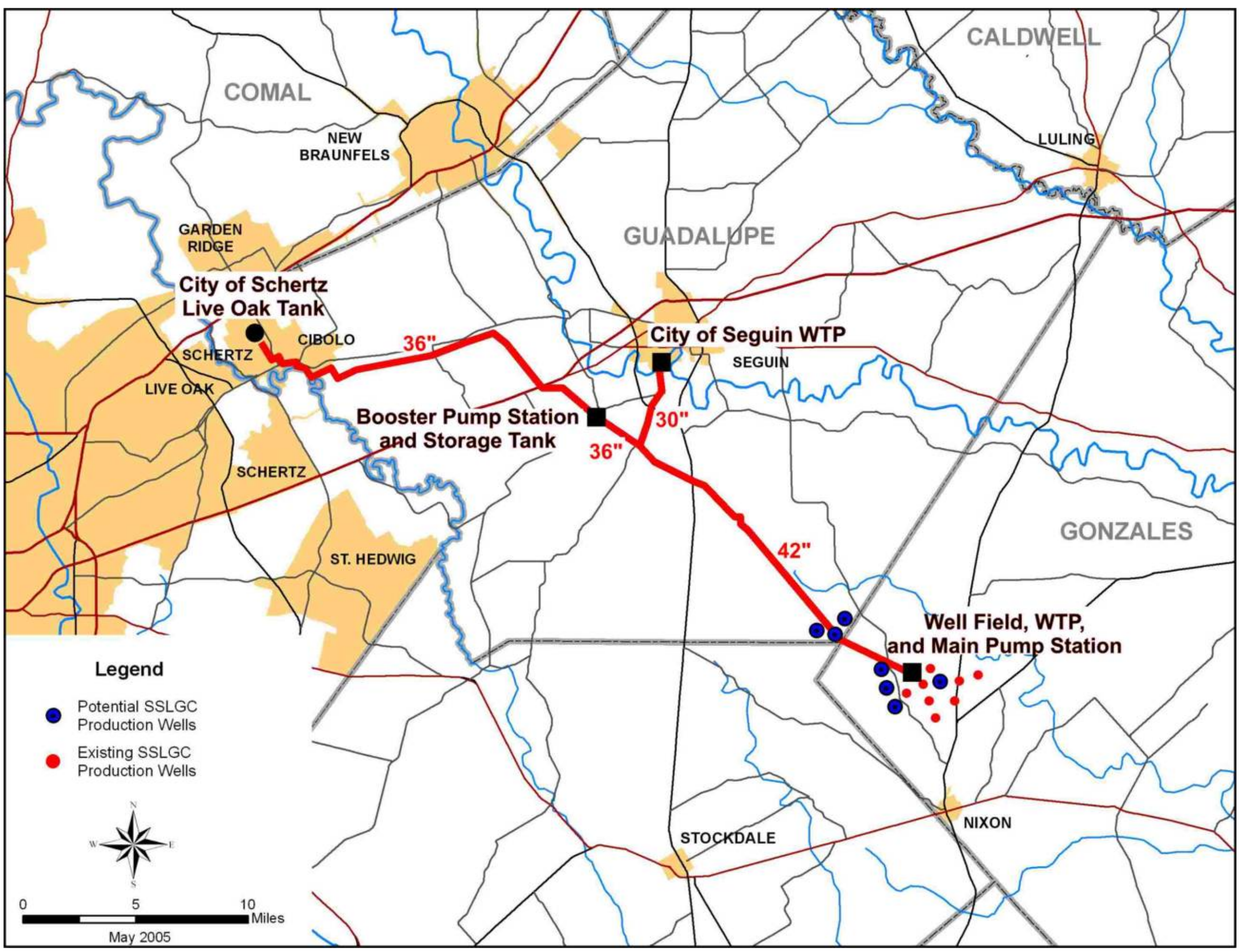


Figure 4C.15-1. Schertz-Seguin Water Supply Project

4C.15.2 Available Yield and Project Drawdown

The SSLGC plans to lease and acquire land for expansion of the project. Plans include expanding the Western Gonzales County well field by four additional wells by the year 2010, yielding a total of approximately 20,000 acft/yr. Additionally, there are plans for a well field in Guadalupe County consisting of three 1,000-gpm wells (approximately 5,000 acft/yr), resulting in a total project yield of 25,000 acft/yr by the year 2020. Evaluation of this water management strategy does not address the elements of the project presently in place. The evaluation applies only to the proposed expansion of facilities (i.e., seven new wells producing 12,800 acft/yr, expansion of treatment plant facilities, and additional pumping costs). No new pump stations, storage tanks, or conveyance pipelines are considered.

Projected Drawdown

In order to evaluate potential drawdown of the SSLGC project, predictive groundwater modeling simulations were performed with identical pumpage using both the South Central Carrizo System (SCCS) groundwater model and the southern Carrizo-Wilcox/Queen City-Sparta Aquifers (SCWQSGAM). Annual SSLGC pumpage for these simulations was assumed to be 100 percent of the pumpage displayed in Figure 4C.15-2 and presented in Table 4C.15-1. This is consistent with information provided by representatives of SSLGC pursuant to a coordination meeting held October 13, 2004 in the City of Seguin. The 25,000 acft/yr of pumpage associated with this project was added to the pumpage for local supply simulated in the baseline runs as described in Section 4C.12. The resulting total drawdown from the combined pumpage is presented in Figures 4C.15-3 and 4C.15-4. The SCCS model calculates a maximum 10-foot drawdown contour of 80 feet at the project location in 2060. The SCWQSGAM calculates a maximum drawdown contour of 100 feet at the site.

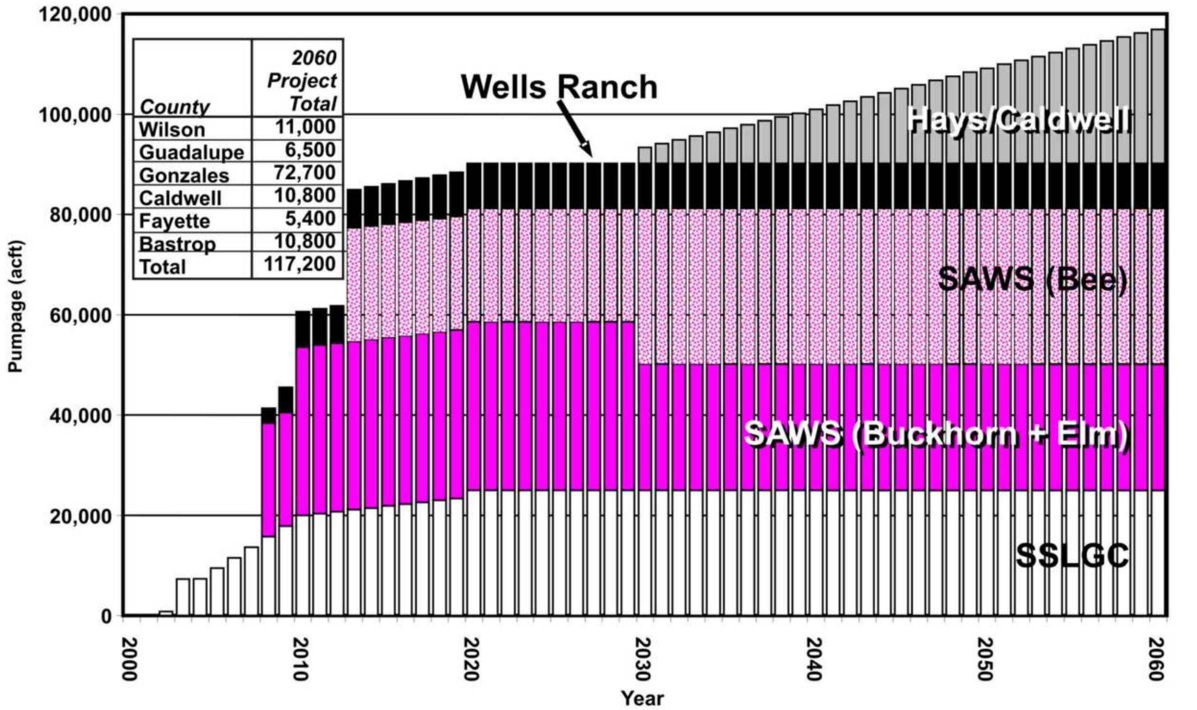


Figure 4C.15-2. Carrizo Groundwater WMS Predictive Pumpage

Table 4C.15-1.
Carrizo Groundwater WMS Predictive Pumpage

Year	*SSLGC*	*SAWS Buckhorn*	*SAWS Elm*	*SAWS Bee*	*Wells Ranch*	*Hays/ Caldwell*	*Total*
2002	796	0	0	0	0	0	796
2008	11,794	22,600	0	0	3,000	0	37,394
2010	20,000	22,600	11,000	0	7,000	0	60,600
2013	21,500	22,600	11,000	22,600	7,600	0	85,300
2020	25,000	22,600	11,000	22,600	9,000	0	90,200
2030	25,000	16,950	8,250	31,000	9,000	3,168	93,368
2040	25,000	16,950	8,250	31,000	9,000	10,757	100,957
2050	25,000	16,950	8,250	31,000	9,000	18,981	109,181
2060	25,000	16,950	8,250	31,000	9,000	27,000	117,200

The drawdown attributable to the SSLGC project was separated from drawdown due to local pumpage using the method described in Section 4C.14. The SCCS Model calculates a maximum drawdown of 70 feet attributable to the SSLGC project (Figure 4C.15-5), while the SCWGAM calculates a maximum drawdown of 80 feet at the project site (Figure 4C.15-6).

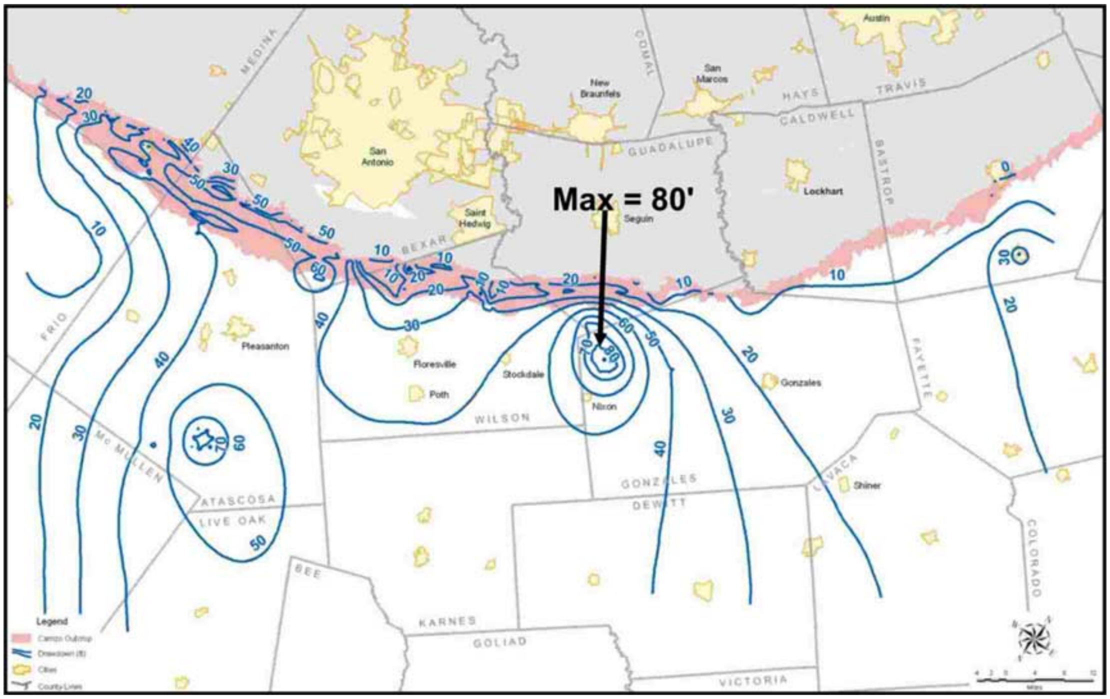


Figure 4C.15-3. SCCS 2002 to 2060 Drawdown: Local Supply + SSLGC

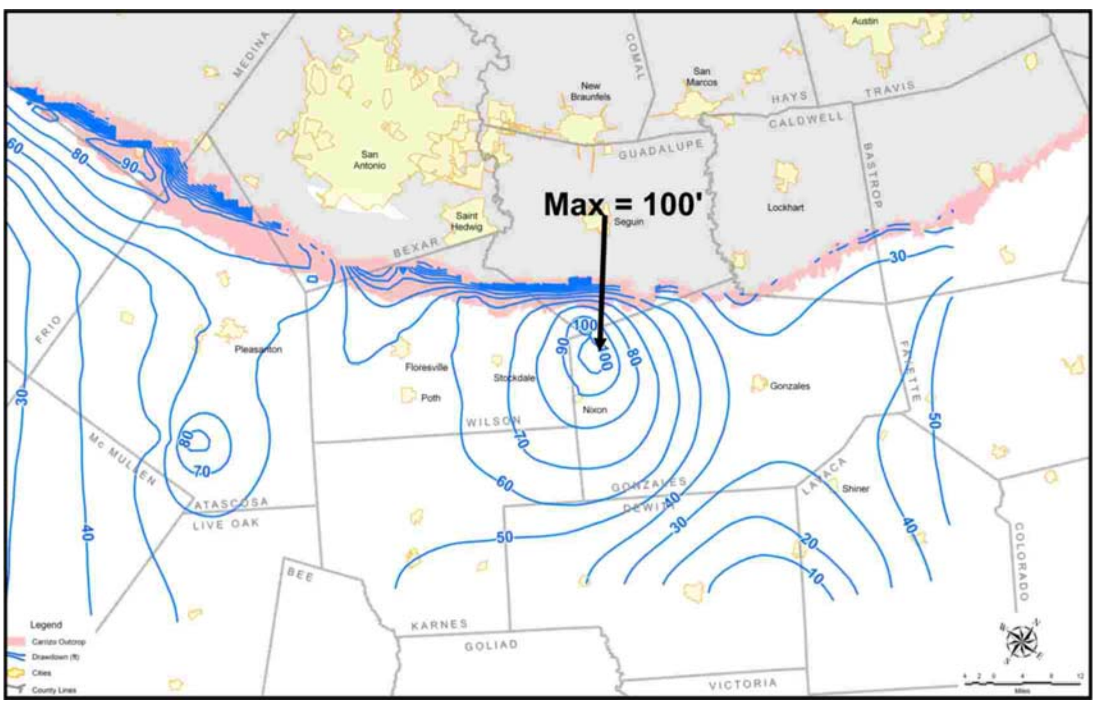


Figure 4C.15-4. SCWQSGAM 2002 to 2060 Drawdown: Local Supply + SSLGC

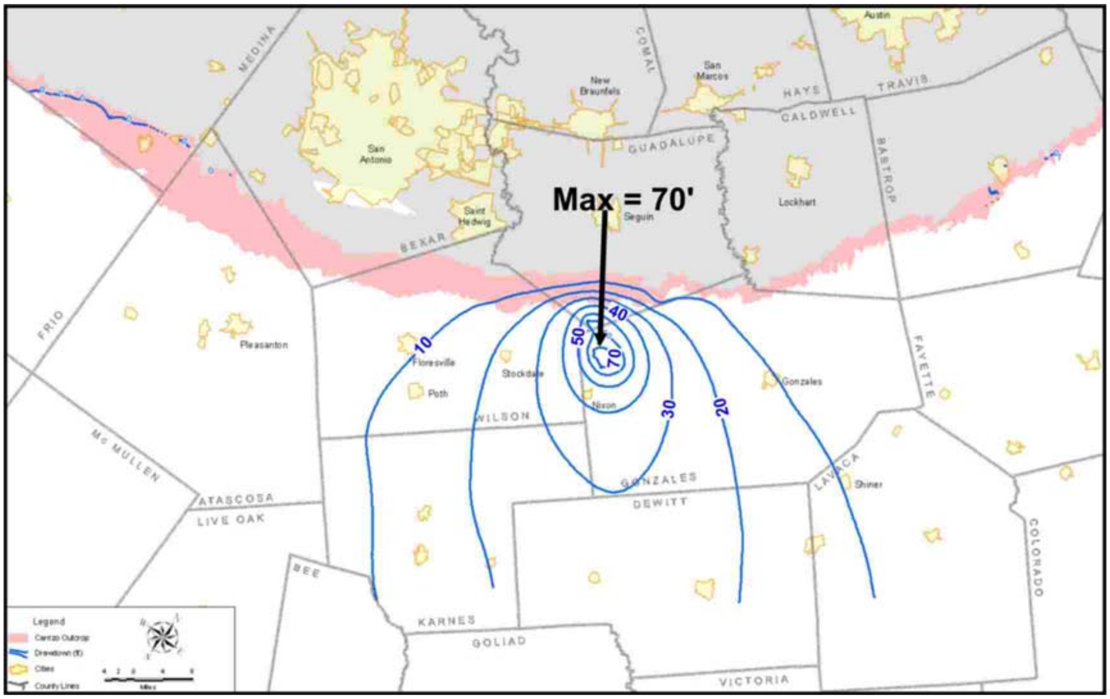


Figure 4C.15-5. SCCS 2002 to 2060 Drawdown Attributable to SSLGC

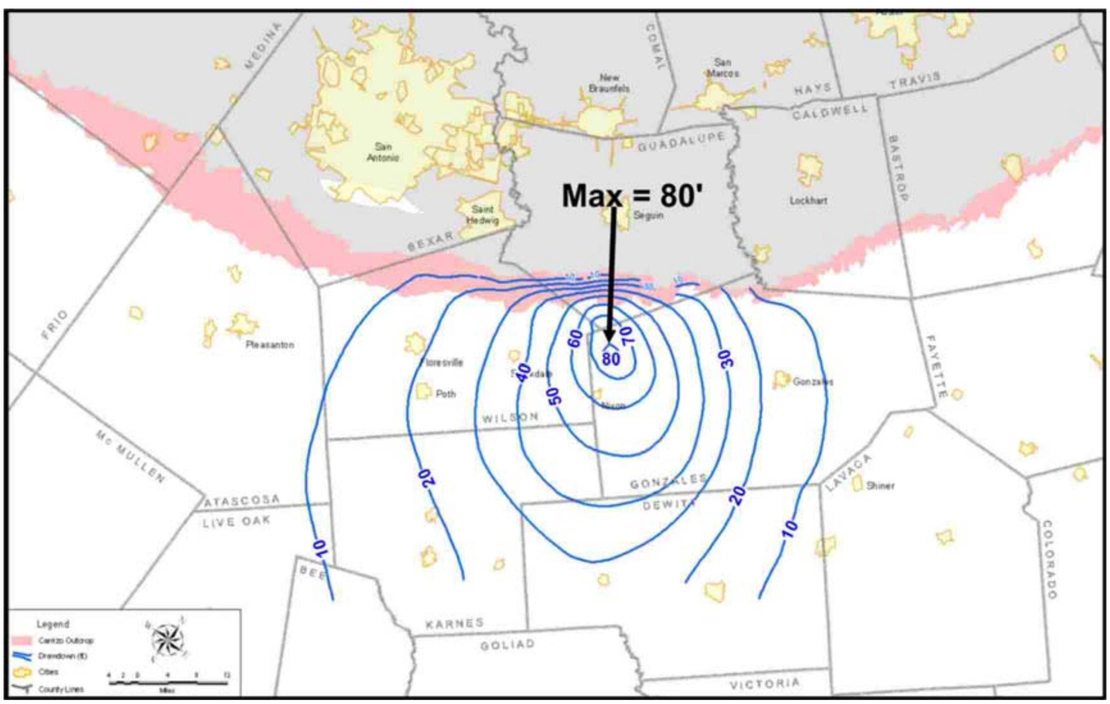


Figure 4C.15-6. SCWQSGAM 2002 to 2060 Drawdown Attributable to SSLGC

In order to examine the change in drawdown with time associated with the project, hydrographs were developed for the 2002 to 2060 simulation period at communities of interest that surround the project location. Hydrographs associated with the four predictive scenarios of Local Supply Pumpage, Local Supply + SSLGC, Local Supply + SSLGC + SAWS, and Local Supply + All Projects were previously displayed in Figures 4C.14-9 (SCCS) and 4C.14-10 (SCWQSGAM).

4C.15.3 Environmental Issues

The Regional Carrizo for SSLGC Project Expansion involves the expansion of an existing well field in western Gonzales County and its current treatment facilities and the construction of a new well field in Guadalupe County. This report section discusses the potential impacts to environmental and cultural resources known to exist within the proposed well field areas.

The project area includes land primarily in the Post Oak Savannah vegetational area, with the eastern end of the proposed well field entering into the edges of the Blackland Prairies vegetational area.[1] The vegetation of this portion of Guadalupe and Gonzales Counties is now primarily composed of rangeland and crops and post-oak woodlands. Common woody species include post oak (*Quercus stellata*), blackjack oak (*Quercus marilandica*), and species of *Carya* (hickory). Grasses of the area commonly include little bluestem (*Schizachyrium scoparium*), indiangrass (*Sorghastrum nutans*) and switchgrass (*Panicum virgatum*).[2] Pricklypear (*Opuntia sp.*) is common throughout most of the area.[3]

The eastern end of the existing well field is located in the Blackland Prairies vegetational area in Gonzales County. This rolling and well-dissected vegetational area was historically a luxuriant tallgrass prairie dominated by little bluestem (*Schizachyrium scoparium* var. *frequens*), big bluestem (*Andropogon gerardii*), indiangrass (*Sorghastrum nutans*), and dropseeds (*Sporobolus sp.*).[4] During the turn of the 20th century, the majority of the Blackland Prairie was cultivated for crops. Livestock production has increased dramatically since the 1950s and now

[1] Gould, F.W., "The Grasses of Texas," Texas A&M University Press, College Station, Texas, 1975.
[2] Ibid.
[3] Hatch, S.L., K.N. Gandhi, and L. E. Brown, "Checklist of the Vascular Plants of Texas," Texas Agricultural Experiment Station, Texas A & M University, College Station, 1990.
[4] Gould, F.W., "The Grasses of Texas," Texas A&M University Press, College Station, Texas, 1975

only about half of the area is used for cropland. Grazing pressure has increased grass species such as sideoats grama (*Bouteloua curtipendula*), hairy grama (*B. hirsuta*), Mead's sedge (*Carex meadii*), Texas wintergrass (*Stipa leucotricha*) and buffalograss (*Buchloe dactyloides*). Common woody species include mesquite, huisache (*Acacia smallii*), oak (*Quercus sp.*) and elm (*Ulmus sp.*). Oak, elm, cottonwood (*Populus sp.*) and native pecan (*Carya*) are common along drainages.

Vertebrate fauna typifying these regions include the opossum, raccoon, weasel, skunk, white-tailed deer and bobcat as well as a wide variety of amphibians, reptiles and birds. The coyote and javelina are also common to the area, but are found mainly in brush/shrub areas while the red and gray fox are more common in woodlands.[5]

Plant and animal species listed by the USFWS and TPWD as endangered, threatened or rare in the project area are presented in Table 4C.15-2. Within the well field areas, several species listed as threatened by the state may possibly have habitat, which will be affected. These include the Texas Horned Lizard (Phrynosoma cornutum), Texas Tortoise (Gopherus berlandieri), and Timber/Canebrake Rattlesnake (Crotalus horridus).

The Texas Parks and Wildlife Department map files of the Wildlife Science Research and Diversity Division system files identifies several plant species of concern in the vicinity of the well field area. These species include Elmendorf's onion (*Allium elmendorfii*), Sandhill Woolywhite (Hymenopappus carrizoanus), and Park's jointweed (*Polygonella parksii*). Both Elmendorf's onion and Parks' jointweed are found in deep sands. These species of concern are considered to be rare, but are not protected by USFWS or TPWD.

Concerns associated with the expansion of the existing well field and development of the new well field area involve water levels in the aquifer, baseflow of the surrounding streams and wetlands. The possibility exists that water levels in the aquifer, affected by the additional wells, could decrease before stabilizing, thus affecting habitat within the area. Waters of the U.S. crossings within the well field area consists of the riverine habitat of Sandies Creek, as well as associated palustrine habitats that are generally composed of narrow bands of wetlands adjacent to this watercourse. Although the USFWS National Wetlands Inventory (NWI) maps identify both temporary and permanent palustrine wetlands adjacent to the well fields, a ground survey wetland delineation will be required to determine which of these and other features would be

[5] Jones, J.K. et al., "Annotated Checklist of Recent Land Mammals of Texas," Occasional Papers of the Museum OP-119, Texas Tech University, 1988.

Table 4C.15-2.
Rare and Protected Species in the Regional Carrizo for SSLGC Project Area

Common Name	Scientific Name	Impact Value	Multiplier Based on Status	Adjusted Impact	Summary of Habitat Preference	Listing Entity		Potential Occurrence in County
						USFWS[1]	TPWD[1]	
American Peregrine Falcon	*Falco peregrinus anatum*	0	3	0	Open country; cliffs	DL	E	Nesting/Migrant
Arctic Peregrine Falcon	*Falco peregrinus tundrius*	0	2	0	Open country; cliffs	DL	T	Nesting/Migrant
Bald Eagle	*Haliaeetus leucocephalus*	0	2	0	Large bodies of water with nearby resting sites	LT-PDL	T	Nesting/Migrant
Big Red Sage	*Salvia penstemonoides*	0	1	0	Endemic; Creekbeds and seepage slopes of limestone canyons			Resident
Blue Sucker	*Cycleptus elongatus*	0	2	0	Channels and flowing pools with exposed bedrock		T	Resident
Cagles Map Turtle	**Graptemys caglei**	1	2	2	Waters of the Guadalupe River Basin	C1	T	Resident
Cave Myotis Bat	**Myotis velifer**	0	1	0	Colonial & cave dwelling; hibernates in limestone caves of Edwards Plateau			Resident
Elmendorfs Onion	*Allium elmendorfii*	2	1	2	Endemic; deep sands derived from Queen City and similar Eocene formations			Resident
Guadalupe Bass	*Micropterus treculi*	1	1	1	Streams of eastern Edwards Plateau			Resident
Guadalupe Darter	*Percina sciera apristis*	1	1	1	Raceways of medium streams and rivers.			
Henslows Sparrow	*Ammodramus henslowii*	1	1	1	Weedy fields or cut over areas; bare ground for running and walking			Nesting/Migrant
Interior Least Tern	*Sterna antillarum athalassos*	1	3	3	Inland river sandbars for nesting and shallow water for foraging	LE	E	Nesting/Migrant
Keeled Earless Lizard	*Holbrookia propinqua*	0	1	0	Coastal dunes, Barrier islands and sandy areas			Resident
Mountain Plover	*Charadrius montanus*	0	1	0	Shortgrass plains and fields, sandy deserts, plowed fields			Nesting/Migrant
Palmetto Pill Snail	*Euchemotrema leai cheatumi*	0	1	0	Terrestrial snail from Palmetto State Park.			Resident

Table 4C.15-2. Continued

Parks Jointweed	*Polygonella parksii*	2	1	2	South Texas Plains; subherbaceous annual in deep loose sands, spring-summer			Resident
Plains Spotted Skunk	*Spilogale putorius interrupta*	0	1	0	Catholic; Wooded, brushy areas and tallgrass prairies			Resident
Sandhill Woolywhite	*Hymenopappus carrizoanus*	2	1	2	Endemic; Open areas in deep sands derived from Carrizo and similar Eocene formations			Resident
Texas Garter Snake	*Thamnophis sirtalis annectens*	1	1	1	Varied, especially wet areas; bottomlands and pastures			Resident
Texas Horned Lizard	*Phrynosoma cornutum*	1	2	2	Varied, sparsely vegetated uplands		T	Resident
Texas Salamander	*Eurycea neotenes*	0	1	0	Endemic, from springs, seeps and caves.			Resident
Texas Tortoise	*Gopherus berlandieri*	2	2	4	Open brush with grass understory; open grass and bare ground avoided; occupies shallow depressions at base of bush or cactus, underground burrows, under objects; active March-Nov		T	Resident
Timber/Canebrake Rattlesnake	*Crotalus horridus*	1	2	2	Bottomland hardwoods		T	Resident
Whooping Crane	*Grus americana*	0	3	0	Potential migrant	LE	E	Migrant
Wood Stork	*Buteo americana*	0	2	0	Prairie ponds, flooded pastures or fields; shallow standing water		T	Nesting/Migrant

[1] ***Texas Parks and Wildlife Department (TPWD), Unpublished 2005, March 2005, Data and Map Files of the Wildlife Science Research and Diversity Division maintained by TPWD, Austin, Texas.***

* LE/LT=Federally Listed Endangered/Threatened E/SA, T/SA=Federally Listed Endangered/Threatened by Similarity of Appearance
C1=Federal Candidate for Listing DL, PDL=Federally Delisted/Proposed for Delisting NL=not Federally Listed E, T=State Listed Endangered/Threatened
PE, PT=Federally Proposed Endangered/ Threatened Blank = Rare, but no regulatory listing status

affected and to what extent. The wetland delineation will document the locations of streambeds, stream widths, quality and type of water bodies, types of aquatic vegetation, presence of special aquatic resources (such as wetlands) and area of jurisdictional Waters of the U.S. likely to be disturbed during construction. Perennial streams such as Sandies Creek are of greatest concern. A wetland delineation must be conducted on the well pads, access roads and other areas to be disturbed during construction.

Most of the proposed well field areas have not been subjected to systematic archeological survey. Therefore, the available information on site occurrence is incomplete. An archeological survey of the project area should be undertaken to more accurately determine actual impacts to cultural resources. Cultural resources protection on public lands in Texas is afforded by the Antiquities Code of Texas (Title 9, Chapter 191, Texas Natural Resource Code of 1977), the National Historic Preservation Act (Pl96-515), and the Archeological and Historic Preservation Act (PL93-291). Cultural resource occurrences within this project area are expected to be present due to the well fields' location near Sandies Creek. Considering that the owner or controller of the project will likely be a political subdivision of the State of Texas (i.e. river authority, municipality, county, etc.), they will be required to coordinate with the Texas Historical Commission prior to project construction. If the project will affect waters of the United States or wetlands, the project sponsor will also be required to coordinate with the U.S. Army Corps of Engineers regarding impacts to cultural resources.

4C.15.4 Engineering and Costing

Groundwater will be developed by constructing seven new wells and expanding existing treatment facilities for chlorine disinfection and iron/manganese removal. Other than well field collection piping, no new conveyance pipeline segments are to be constructed.

The SSLGC expansion is planned to provide an additional 12,800 acft/yr above and beyond the current capacity. The major facilities required for this strategy are:

- Wells
- Well field collection pipeline(s)
- Water Treatment Plant (Upgrade of Existing Plant).

The approximate locations of these facilities are displayed in Figure 4C.15-1.

Cost estimates were developed in accordance with the methodology for Region L planning studies (Appendix A). Wells located in Gonzales County were assumed to be 1200 feet deep, similar to the existing wells. The Guadalupe County wells were assumed to be 800 feet deep since they are located updip of the existing wells. Power costs for conveyance of the additional 12,800 acft/yr associated with the SSLGC expansion were estimated by calculating the power costs necessary to pump the presently-permitted amount of 12,200 acft/yr through the existing pipeline, then calculating the power costs to pump the full project pumpage of 25,000 acft/yr through the pipeline. These two costs were subtracted to obtain the incremental power cost associated with pumping the additional 12,800 acft/yr associated with the project expansion. No new cost estimates were developed for existing pump station, storage tanks, or pipelines. Costs were included for leasing property necessary to obtain permits, and for anticipated third party well mitigation activities to compensate for lowered pumping levels in existing wells.

Based on these assumptions, and on an assumed yield of 12,800 acft/yr, it is estimated that the water obtained through the water management strategy of SSLGC project expansion will have a unit cost of $411/acft, or $1.26/1,000 gallons (Table 4C.15-3).

4C.15.5 Implementation Issues

Implementation of the Regional Carrizo to Bexar County option could involve limited conflicts with other water supply options under consideration, including Regional Carrizo to Bexar County, Wells Ranch Carrizo project, and/or Hays/Caldwell Carrizo project since each of these will be operating all or in part in common groundwater conservation districts.

This project was evaluated in conformance with the existing rules of the Gonzales County UWCD. Part of the supply developed by this project exceeds the amount of available water identified in the current Gonzales County UWCD management plan. The amount of water needed by the project that exceeds the available water in the management plan cannot be implemented unless and until permits are received from the Gonzales County UWCD. This project does not cause the Gonzales UWCD management plan to be in conflict with the South Central Texas Regional Water Plan. See Public Comments and SCTRWPG Response Developed through Facilitation for Issue Number 6 in Section 10.2.2.3.

Table 4C.15-3.
Cost Estimate Summary
Regional Carrizo for SSLGC Project Expansion
Second Quarter 2002 Prices

Item	***Estimated Costs for Facilities***
Capital Costs	
Well Fields	$7,091,000
Water Treatment Plant (11.4 MGD)	8,638,000
Total Capital Cost	**$15,729,000**
Engineering, Legal Costs and Contingencies	$5,505,000
Environmental & Archaeology Studies and Mitigation	250,000
Groundwater Lease Acquisition[1]	1,406,000
Mitigation Reserve for Possible Impacts to Local Wells[1]	$2,734,000
Interest During Construction (1 year)	$1,025,000
Total Project Cost	**$26,649,000**
Annual Costs	
Debt Service (6 percent for 30 years)	$1,936,000
Groundwater Lease Payments[1]	$804,000
Operation and Maintenance:	
Wells, Pipeline, Pumps	71,000
Water Treatment Plant	997,000
Pumping Energy Costs (2,168,133 kWh @ $0.06/kWh)	1,351,000
District Export Fee ($0.025 per 1,000 gallons)	104,000
Total Annual Cost	**$5,263,000**
Available Project Yield (acft/yr)	**12,800**
Annual Cost of Water ($ per acft)	**$411**
Annual Cost of Water ($ per 1,000 gallons)	**$1.26**

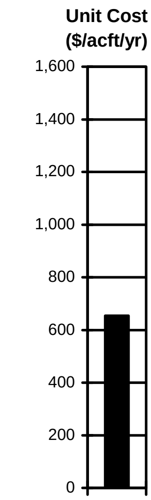
Groundwater lease and mitigation costs are consistent with detailed costs developed during evaluation of Regional Carrizo to Bexar County WMS (4C.14)

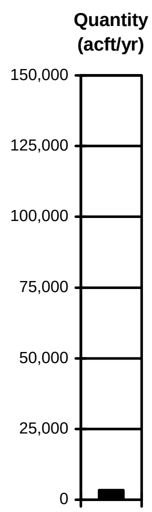
The development of groundwater in the Carrizo-Wilcox Aquifer in the South Texas Water Planning Region must address several issues. Major issues include:

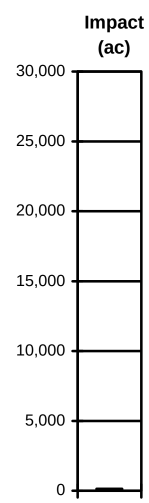
- Detailed feasibility evaluation including test drilling and aquifer and water quality testing, followed with more detailed groundwater modeling to confirm results of this preliminary evaluation. This has been largely accomplished through the operation of the SSLGC well field since startup in October 2002.
- Impact on:
  - Endangered and threatened wildlife species,
  - Water levels in the aquifer,
  - Baseflow in streams, and
  - Wetlands.
- Competition with others in the area for groundwater.
- Regulations by the Evergreen UWCD and Gonzales County UWCD, including the renewal of pumping permits at 5-year intervals.
- Water levels did not completely stabilize during the 59-year simulation and if all proposed pumpage continues at 100 percent of project plans, water levels could continue to decrease for some time before stabilizing.

(This page intentionally left blank.)

2006 South Central Texas Regional Water Plan
Water Management Strategy Summary Sheet







Name: Wells Ranch Project

Description: Water management strategy to be developed by Bexar Metropolitan Water District (BMWD) includes a shared well field in Gonzales and Guadalupe Counties to deliver a total of about 9,000 acft/yr (3,400 acft/yr for this strategy) of Carrizo Aquifer groundwater to the Canyon Regional Water Authority (CRWA) Wagner Pump Station in Guadalupe County. Facilities are shared with the CRWA Dunlap Project and include 18 x500-gpm wells in Gonzales & Guadalupe Counties, collection system, water treatment plant, transmission pump station, and a 30-mile 30-inch transmission pipeline. Facilities sized for delivery on a peak month basis for municipal supply. (For the purposes of modeling anticipated drawdown, this project was considered along with CRWA's Dunlap Project.)

***Decade Needed*:** 2000-2010

Cost, Quantity of Water, and Land Impacted

Unit Cost of Water:	**690**	**$/acft/yr**	**Treated Water Delivered**
Quantity of Water:	**3,400**	**acft/yr**	**Reliability = Firm**
Land Impacted:	**131**	**acres**	**Pipeline ROW, wellheads, pump stations**

Additional Considerations per Regional Water Planning Guidelines

Environmental Factors:
Threatened species include the Texas Horned Lizard, the Texas Tortoise, and the Cagle's Map Turtle. Groundwater pumpage could affect springflows and base streamflows.

Impacts on Water Resources:
Long-term reductions in aquifer levels.

Impacts on Agricultural & Natural Resources:
Minimal, if any.

Other Relevant Factors per SCTRWPG:
Gonzales County Underground Water Conservation District (GCUWCD) and the Guadalupe County Groundwater Conservation District have rules and management plans that need to be considered in project planning. Local GCDs have permitting authority over any export project within their jurisdiction. This project was evaluated in conformance with the existing rules of the Gonzales County UWCD. Part of the supply developed by this project exceeds the amount of available water identified in the current Gonzales County UWCD management plan. The amount of water needed by the project that exceeds the available water in the management plan cannot be implemented unless and until permits are received from the Gonzales County UWCD. This project does not cause the Gonzales UWCD management plan to be in conflict with the South Central Texas Regional Water Plan. See Public Comments and SCTRWPG Responses Developed through Facilitation for Issues 2, 5, and 6 in Section 10.2.2.3. An agreement between BMWD and Guadalupe County GCD limits pumpage from Wells Ranch in Guadalupe County to 1,400 acft/yr.

Comparison of Strategies to Meet Needs:
Limited conflicts with other recommended water strategies including SSLGC Project Expansion, CRWA Dunlap Project, Hays/Caldwell Carrizo Project, and/or Regional Carrizo for Bexar County Supply.

Interbasin Transfer Issues:
Not applicable.

Third-Party Impacts of Voluntary Transfers:
Mitigation (i.e., lowering of pumps, drilling of new wells, etc.) is required by GCDs for affected third parties.

Regional Efficiency:
New supply proximate to water user group in Bexar County.

Water Quality Considerations:
Carrizo-Wilcox water may contain high iron and manganese concentrations.

(This page intentionally left blank.)

4C.16 Wells Ranch Project

4C.16.1 Description of Water Management Strategy

Bexar Metropolitan Water District (BMWD) has been in the exploratory phase of a well field at Wells Ranch, straddling the border of Guadalupe and Gonzales Counties, for several years. To date, BMWD has obtained drilling/production permits for three wells from the Gonzales County Underground Water Conservation District (GCUWCD), and has conducted some performance testing. An earlier version of this project appeared in the 2001 South Central Texas Regional Water Plan (SCTRWP) as a water management strategy identified as "Carrizo Aquifer – Bexar and Guadalupe (BMWD)". The strategy identified an estimated supply of 4,000 acft/yr in the 2001 plan, and did not explicitly identify Gonzales County as a source location.

During the intervening 5 years, the strategy from the 2001 plan has evolved into a project jointly sponsored by BMWD and Canyon Regional Water Authority (CRWA), and is now an integral component of two water management strategies. The overall concept envisions production of up to 9,000 acft/yr from the Carrizo Aquifer from a well field located in Gonzales and Guadalupe Counties. BMWD and CRWA each have complementary plans for portions of the total 9,000 acft/yr to be produced at the well field. CRWA would use up to 5,600 acft/yr of the groundwater as part of the Lake Dunlap Project (described in Section 4C.24). BMWD would use the remaining 3,400 acft/yr, after treatment and transmission from the well field to the CRWA Wagner Pump station in Guadalupe County, for its customers in Bexar County. This section describes BMWD's water management strategy, identified herein as the Wells Ranch Project (Figure 4C.16-1).

4C.16.2 Water Availability

The Carrizo Aquifer in areas south and east of the source area identified for this project has proven to be very productive, with high capacity wells in the confined section of the aquifer routinely capable of producing in excess of 1,000 gpm. As the proposed well field for the Wells Ranch Project is located much closer to the outcrop, long-term production capacities are expected to be less than 1,000 gpm. Based on performance testing of existing wells, recommendations of a consultant to BMWD,[1] and current permit conditions with GCUWCD, a production capacity of 500 gpm has been adopted for this technical evaluation.

[1] R.W. Harden & Associates, Wells Ranch Well Field Evaluation, November 2000.

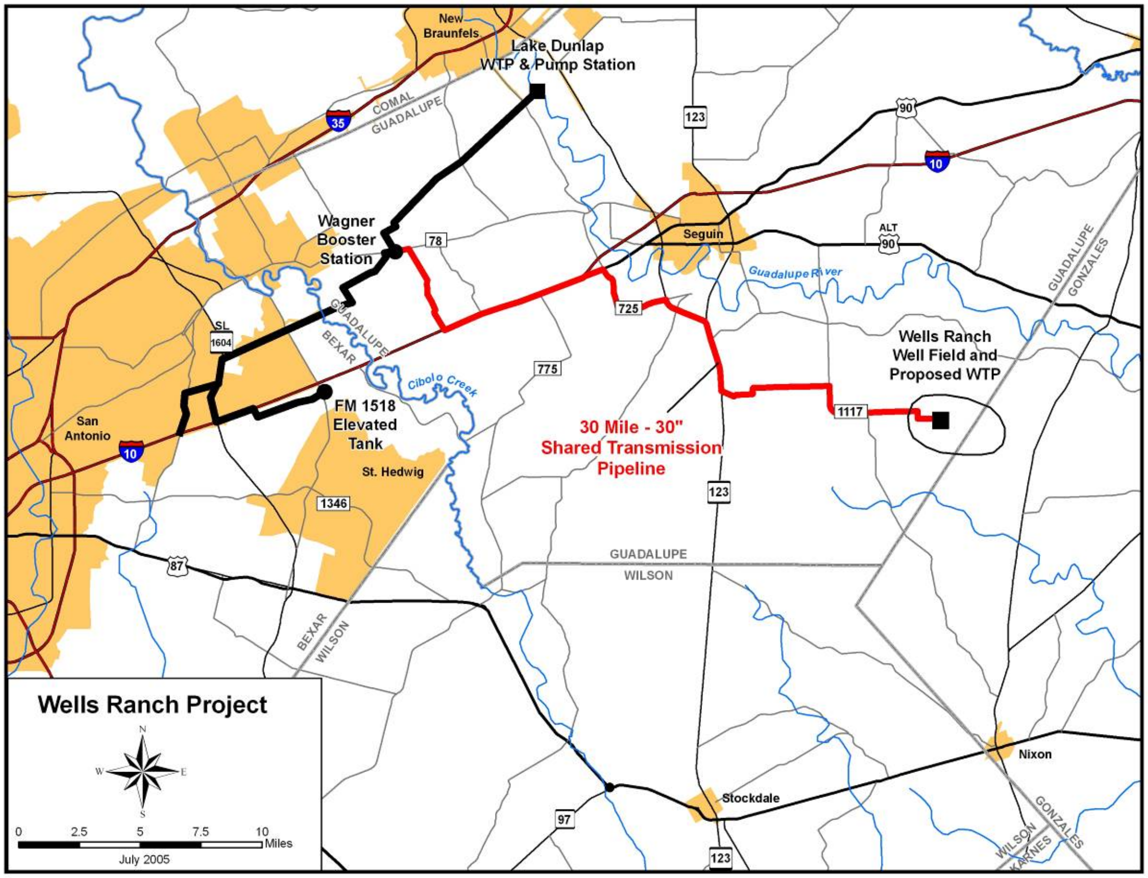


Figure 4C.16-1. Wells Ranch Project (BMWD) Location Map

On October 13, 2004, a coordination meeting was held in the City of Seguin at which the SCTRWPG solicited input from CRWA and BMWD regarding the quantity of groundwater pumpage that they were interested in seeing modeled during the water management strategy evaluation. BMWD responded that they anticipated reaching their ultimate goal of pumping 9,000 acft/year from the Wells Ranch well field by the year 2020. This is the amount that was included in predictive groundwater model simulations conducted in support of the water management strategy evaluation, and later in the cumulative effects evaluation. Estimated pumpage associated with all Carrizo groundwater WMS projects is displayed in Figure 4C.16-2 and presented in Table 4C.16-1.

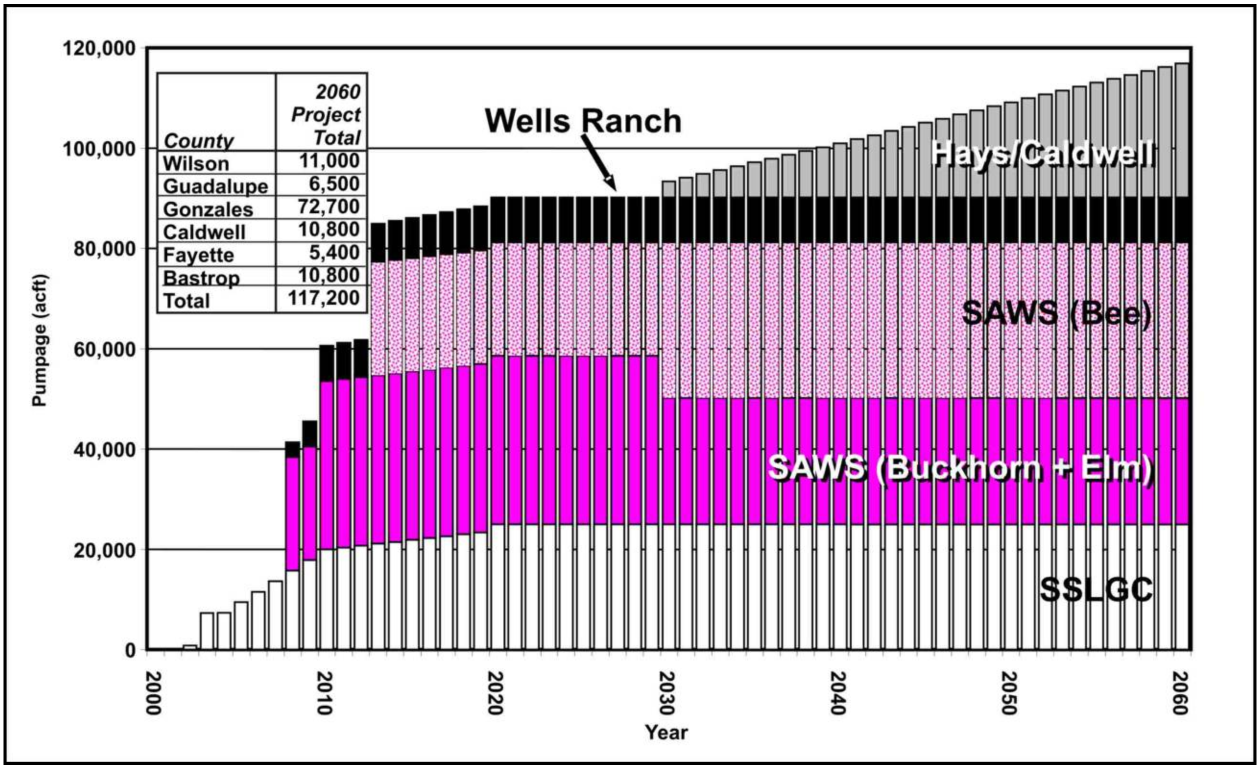


Figure 4C.16-2. Carrizo Groundwater WMS Predictive Pumpage

Table 4C.16-1.
Carrizo Groundwater WMS Predictive Pumpage

Year	*SSLGC*	*SAWS Buckhorn*	*SAWS Elm*	*SAWS Bee*	*Wells Ranch*	*Hays/ Caldwell*	*Total*
2002	796	0	0	0	0	0	796
2008	11,794	22,600	0	0	3,000	0	37,394
2010	20,000	22,600	11,000	0	7,000	0	60,600
2013	21,500	22,600	11,000	22,600	7,600	0	85,300
2020	25,000	22,600	11,000	22,600	9,000	0	90,200
2030	25,000	16,950	8,250	31,000	9,000	3,168	93,368
2040	25,000	16,950	8,250	31,000	9,000	10,757	100,957
2050	25,000	16,950	8,250	31,000	9,000	18,981	109,181
2060	25,000	16,950	8,250	31,000	9,000	27,000	117,200

With respect to the overall availability of 9,000 acft/yr of groundwater from the proposed well field, it is noted that permits for production must be obtained from the Guadalupe County Groundwater Conservation District (GCGCD) as well as the GCUWCD. A settlement agreement between BMWD and the GCGCD has been executed which stipulates that a maximum of 1,400 acft/yr may be pumped from the Wells Ranch property in Guadalupe County. It is assumed for this evaluation that permits for production of the remaining 7,600 acft/yr can be obtained from GCUWCD.

This project was evaluated in conformance with the existing rules of the GCUWCD. Part of the supply developed by this project exceeds the amount of available water identified in the current GCUWCD management plan. The amount of water needed by the project that exceeds the available water in the management plan cannot be implemented unless and until permits are received from the GCUWCD. This project does not cause the GCUWCD management plan to be in conflict with the South Central Texas Regional Water Plan.

The specific predictive simulations that were performed with this project pumpage simulated the entire 9,000 acft/yr of availability as a single pumping center; no effort was made to run separate simulations for the Wells Ranch (3,400 acft/yr) and CRWA Dunlap (up to 5,600 acft/yr) Projects. These simulations also included pumpage for the Hays/Caldwell Carrizo Project, located in Caldwell, Bastrop, Fayette, and northern Gonzales Counties (Section 4C.17). Because the Hays/Caldwell Carrizo Project is located in northern Gonzales County, it is judged to be sufficiently distant to include in the same simulation without having a significant impact on drawdowns calculated for the Wells Ranch Project.

4C.16.2.1 Projected Drawdown

In order to evaluate potential drawdown associated with the Wells Ranch and CRWA Dunlap Projects, predictive groundwater modeling simulations were performed with identical pumpage in the common area represented in both the South Central Carrizo System (SCCS) groundwater model[2] and the Southern Carrizo-Wilcox Queen City-Sparta Groundwater Availability Model[3] (SCWQSGAM). Annual Wells Ranch and CRWA Dunlap Project pumpage for these simulations was assumed to be 100 percent of the pumpage displayed in Figure 4C.14-4, with a combined maximum pumpage of 9,000 acft/yr by 2010 associated with these projects. As was done in the Regional Carrizo for Bexar County strategy evaluation (Section 4C.14) and the SSLGC Project Expansion strategy evaluation (Section 4C.15), the Wells Ranch and CRWA Dunlap Project pumpage was added to the pumpage from previous

[2] HDR Engineering, Inc., "South Central Carrizo System Groundwater Model, SAWS Gonzales Carrizo Project," prepared for the San Antonio Water System, November 2004.
[3] Intera, with Bureau of Economic Geology and R.J. Brandes Company, "Groundwater Availability Model for the Queen city and Sparta Aquifers," prepared for the Texas Water Development Board, October 2004.

runs, so that pumpage for local supply and other project pumpage would be included in the simulations.

The resulting total combined drawdown from local baseline plus all project pumpage (SSLGC, SAWS, Wells Ranch, and Hays/Caldwell) is presented in Figures 4C.16-3 and 4C.16-4. The SCCS model calculates a maximum 10-foot drawdown contour of 120 feet at the project location in 2060. The SCWQSGAM calculates a maximum drawdown contour of 180 feet at the site.

The drawdown attributable to the Wells Ranch and CRWA Dunlap Projects was separated from drawdown due to local pumpage and other projects using the method described in Section 4C.14. Both the SCCS Model and the SCWQSGAM calculate a maximum drawdown of about 60 feet attributable to the Wells Ranch and CRWA Dunlap Projects (Figure 4C.16-5, 4C.16-6).

In order to examine the change in drawdown with time associated with the projects, hydrographs were developed for the 2002 to 2060 simulation period at monitor well locations near the project location in the GCUWCD network. Hydrographs were developed for observation wells sited at the cities of Nixon, Stockdale, Bebe, Smiley, and Gonzales County Monitor Well 17 near the SAWS Bee well field. Hydrographs associated with the four predictive scenarios of Local Supply Pumpage, Local Supply + SSLGC, Local Supply + SSLGC + SAWS, and Local Supply + All Projects are displayed in Figures 4C.14-9 (SCCS) and 4C.14-10 (SCWQSGAM).

4C.16.3 Environmental Issues

The proposed Wells Ranch Project facilities include 38 percent of 18 wells in Gonzales and Guadalupe Counties, a collection system, water treatment plant, transmission pump station, and a 30-mile transmission pipeline. The pipeline route would originate at the Wells Ranch well field in eastern Guadalupe County, and travel in a northwest direction until it intersects with IH-10, then west along IH-10 and finally north, terminating at the Wagner Booster Station on FM 78.

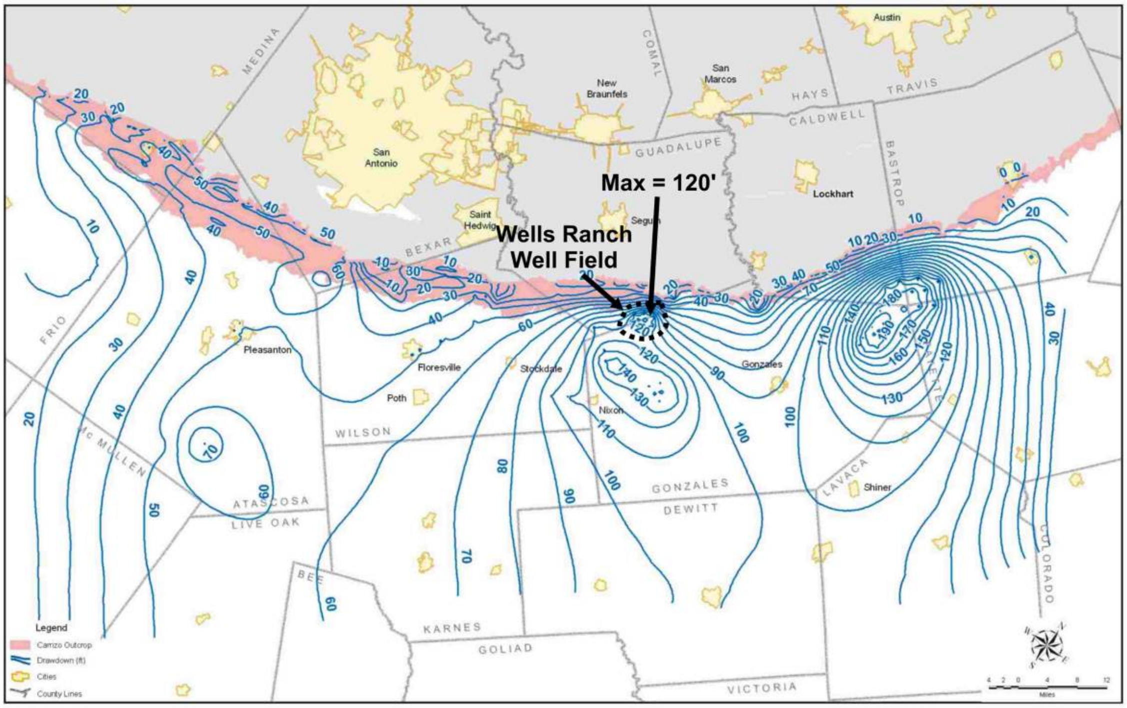


Figure 4C.16-3. SCCS 2002 to 2060 Drawdown: All Projects (with Hays/Caldwell Carrizo Project)

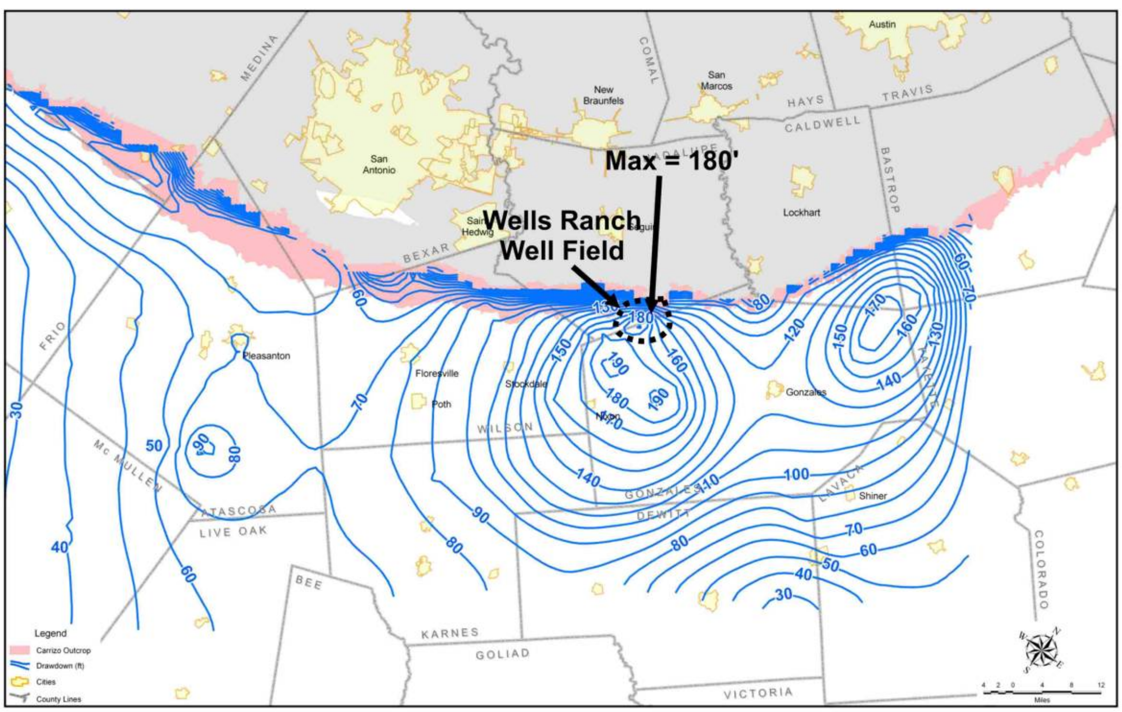


Figure 4C.16-4. SCWQSGAM 2002 to 2060 Drawdown: All Projects (with Hays/Caldwell Carrizo Project)

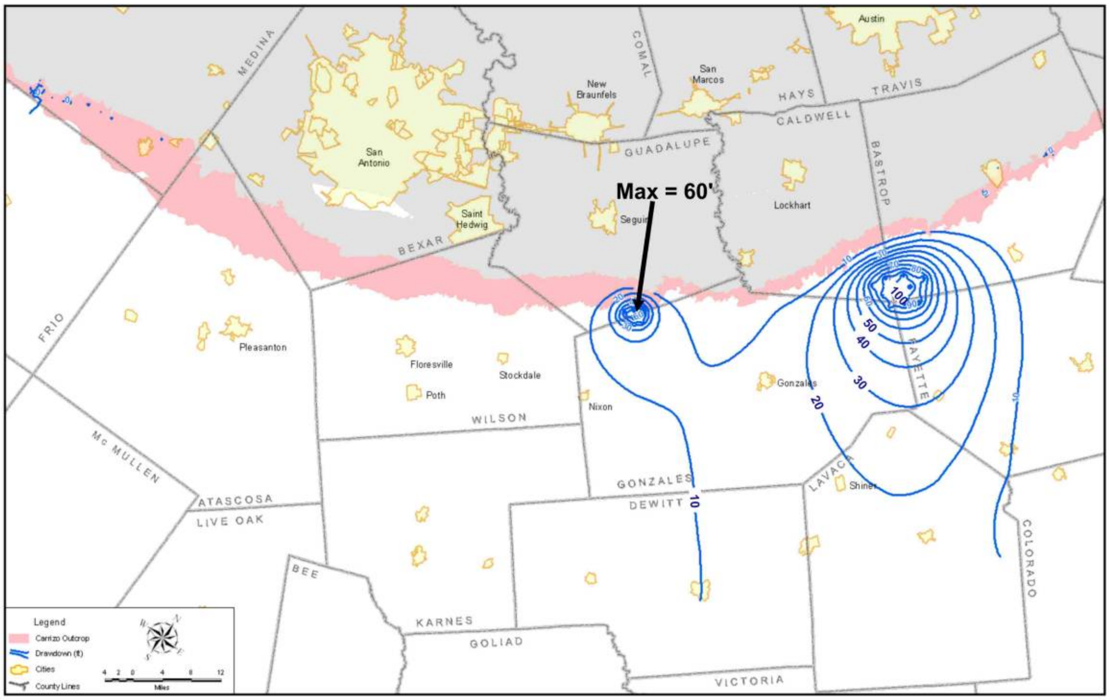


Figure 4C.16-5. SCCS 2002 to 2060 Drawdown Attributable to Wells Ranch and CRWA Dunlap Project (and Hays/Caldwell Carrizo Project)

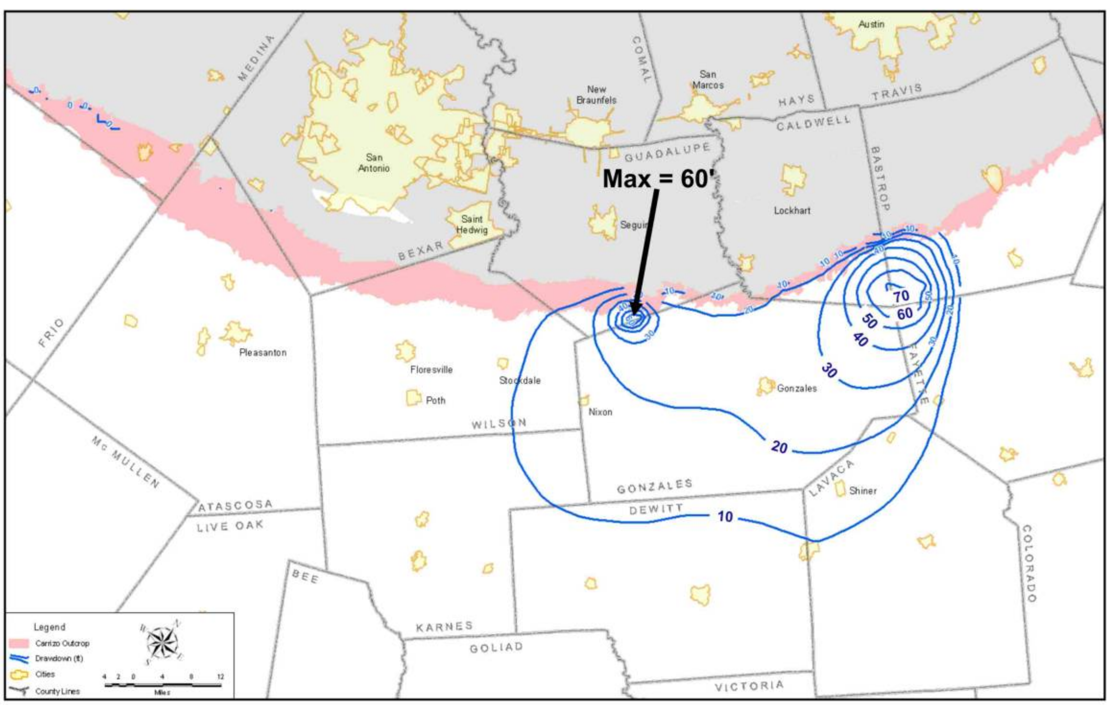


Figure 4C.16-6. SCWQSGAM 2002 to 2060 Drawdown Attributable to Wells Ranch and CRWA Dunlap Project (and Hays/Caldwell Carrizo Project)

The proposed pipeline route would traverse two of Omernik's[4] ecoregions: the East Central Texas Plains, and the westernmost reaches of the Texas Blackland Prairie. The project area would lie in the Texas Blackland Prairies and East Central Texas ecoregions.[5] The dominant vegetation of the Texas Blackland Prairies is mesquite, post oak, bluestems, switchgrass and blackjack oak supported by clay soils mixed with sandy loams. The Post Oak Savannah vegetational area is characterized by gently rolling to hilly terrain with an understory that is typically tall grass and an overstory that is primarily post oak *(Quercus stellata)* and blackjack oak *(Q. marilandica)*. The proposed pipeline corridor is a mosaic of the Post Oak Savannah and the Blackland Prairie ecoregions and could potentially include a wide variety of species. The land use for the area included in the pipeline route is composed of three major vegetation types. The northern section of the route above IH-10 is located in an area usually utilized for crop production. The center portion of the route is situated in a post oak wood and grassland mosaic, and the lower one third of the route traverses a post oak wood or forest.

Although the pipeline route parallels the Guadalupe River along a portion of its course, it does not cross any water sources listed by Texas Parks and Wildlife as Ecologically Significant River and Stream Segments.

Table 4C.16-2 lists rare and protected species that may have habitat in the project area. The Texas Biological and Conservation Data System maintained by TPWD Wildlife Diversity Branch maps several species and essential habitat in the vicinity of the pipeline route. Protected species appear to be primarily those dependent on shrubland or riparian habitat.

Threatened species possibly found within the project area include Cagle's Map Turtle (Graptemys caglei), Texas horned lizard (*Phrynosoma cornutum)*, *Texas* tortoise (*Gopherus berlandieri)*, and the timber/canebrake rattlesnake (*Crotalus horridus)*. The Cagle's map turtle is found only in the waters of the Guadalupe River Basin, the timber/canebrake rattlesnake can be found in woodlands consisting of oak and other hardwoods. The Texas tortoise prefers open brush with grass understory and usually occupies shallow depressions at the base of a bush or cactus, a similar habitat to the Texas horned lizard which occupies sparsely vegetated uplands.

[4] Omernik, J. M, "Ecoregions of the conterminous United States," Annals of the Association of American Geographers, 77: 118-125, 1987.
[5] Gould, F.W., "The Grasses of Texas," Texas A&M University Press, College Station, Texas, 1975.

Table 4C.16-2
Important Species Having Habitat or Known to Occur In Guadalupe County*

Common Name	Scientific Name	Impact Value	Multiplier Based on Status	Adjusted Impact	Summary of Habitat Preference	Listing Entity		Potential Occurrence in County
						USFWS[1]	TPWD[1]	
American Peregrine Falcon	*Falco peregrinus anatum*	0	3	0	Open country; cliffs	DL	E	Nesting/Migrant
Arctic Peregrine Falcon	*Falco peregrinus tundrius*	0	2	0	Open country; cliffs	DL	T	Nesting/Migrant
Big Red Sage	*Salvia penstemonoides*	1	1	1	Endemic; Creekbeds and seepage slopes of limestone canyons			Resident
Cagle's Map Turtle	*Graptemys caglei*	1	2	2	Waters of the Guadalupe River Basin	C1	T	Resident
Cave Myotis Bat	*Myotis velifer*	0	1	0	Colonial & cave dwelling; hibernates in limestone caves of Edwards Plateau			Resident
Elmendorf's Onion	*Allium elmendorfii*	1	1	1	Endemic; deep sands derived from Queen City and similar Eocene formations			Resident
Guadalupe Bass	*Micropterus treculi*	1	1	1	Streams of eastern Edwards Plateau			Resident
Guadalupe Darter	*Percina sciera apristis*	1	1	1	Raceways of medium streams and rivers.			
Henslow's Sparrow	*Ammodramus henslowii*	1	1	1	Weedy fields or cut over areas; bare ground for running and walking			Nesting/Migrant
Interior Least Tern	*Sterna antillarum athalassos*	0	3	0	Inland river sandbars for nesting and shallow water for foraging	LE	E	Nesting/Migrant
Keeled Earless Lizard	*Holbrookia propinqua*	0	1	0	Coastal dunes, Barrier islands and sandy areas			Resident
Mountain Plover	*Charadrius montanus*	1	1	1	Shortgrass plains and fields, sandy deserts, plowed fields			Nesting/Migrant
Parks' Jointweed	*Polygonella parksii*	2	1	2	South Texas Plains; subherbaceous annual in deep loose sands, spring-summer			Resident
Plains Spotted Skunk	*Spilogale putorius interrupta*	0	1	0	Catholic; Wooded, brushy areas and tallgrass prairies			Resident

Table 4C.16-2 (Continued)

Sandhill Woolywhite	*Hymenopappus carrizoanus*	2	1	2	Endemic; Open areas in deep sands derived from Carrizo and similar Eocene formations			Resident
Texas Garter Snake	*Thamnophis sirtalis annectens*	1	1	1	Varied, especially wet areas; bottomlands and pastures			Resident
Texas Horned Lizard	*Phrynosoma cornutum*	2	2	4	Varied, sparsely vegetated uplands		T	Resident
Texas Tortoise	*Gopherus berlandieri*	2	2	4	Open brush with grass understory; open grass and bare ground avoided; occupies shallow depressions at base of bush or cactus, underground burrows, under objects; active March-Nov		T	Resident
Timber/Canebrake Rattlesnake	*Crotalus horridus*	1	2	2	Bottomland hardwoods		T	Resident
Whooping Crane	*Grus americana*	0	3	0	Potential migrant	LE	E	Migrant
Wood Stork	*Buteo americana*	0	2	0	Prairie ponds, flooded pastures or fields; shallow standing water		T	Nesting/Migrant

[1] Texas Parks and Wildlife Department (TPWD), Unpublished 2005, March 2005, Data and Map Files of the Wildlife Science Research and Diversity Division maintained by TPWD, Austin, Texas.

* LE/LT=Federally Listed Endangered/Threatened E/SA, T/SA=Federally Listed Endangered/Threatened by Similarity of Appearance
C1=Federal Candidate for Listing DL, PDL=Federally Delisted/Proposed for Delisting NL=not Federally Listed E, T=State Listed Endangered/Threatened
PE, PT=Federally Proposed Endangered/ Threatened Blank = Rare, but no regulatory listing status

In addition to these species, the proposed pipeline passes in the vicinity of several mapped species of concern: Mountain Plover (Charadrius montanus), Parks jointweed (Polygonella parksii), and Sandhill woollywhite (Hymenopappus carrizoanus). Additional species of concern which may be affected by the pipeline include the Guadalupe Bass (Micropterus treculi), Elmendorf's Onion (Allium elmendorfii), Texas Garter Snake (Thamnophis sirtalis annectens) and big red sage (Salvia penstemonoides).

Field surveys conducted at the appropriate phase of development should be employed to minimize the impacts of construction and operation on sensitive resources. Specific project features, such as well field, pipelines, and off-channel reservoirs generally have sufficient design flexibility to avoid most impacts or significantly mitigate potential impacts to geographically limited environmental and cultural resource sites.

Cultural resources protection on public lands in Texas is afforded by the Antiquities Code of Texas (Title 9, Chapter 191, Texas Natural Resource Code of 1977), the National Historic Preservation Act (P196-515), and the Archeological and Historic Preservation Act (PL93-291). Based on the review of available records housed at the Texas Archeological Research Laboratory in Austin, six cultural resource sites occur within a 1-mile corridor of the proposed project area (Table 4C.16-3). Considering that the owner or controller of the project will likely be a political subdivision of the State of Texas (i.e., river authority, municipality, county, etc.), they will be required to coordinate with the Texas Historical Commission prior to project construction. If the project will affect waters of the United States or wetlands, the project sponsor will also be required to coordinate with the U.S. Army Corps of Engineers regarding impacts to cultural resources.

Table 4C.16-3.
Previously Recorded Cultural Resource Sites within the Proposed Project Area

41GU3	41GU28	41GU35
41GU19	41GU29	41GU36

4C.16.4 Engineering and Costing

Groundwater for the Wells Ranch and CRWA Dunlap Projects will be developed by constructing 18 new wells, a new raw water conveyance pipeline to Wagner Booster Station, and building treatment facilities for chlorine disinfection and iron/manganese removal. BMWD and

CRWA will use common wells, pipeline, and water treatment facilities. Shared costs will be split according to the respective yield to each project, with about 38 percent (3,400/9,000) assigned to the Wells Ranch Project and about 62 percent (5,600/9,000) assigned to the CRWA Dunlap Project.

The Wells Ranch Project is planned to provide an additional 3,400 acft/yr to BMWD by 2010. The major facilities required for this water management strategy that are shared with the CRWA Dunlap Project include:

- 18 Carrizo Aquifer Wells (500 gpm/well),
- Well field collection pipeline,
- 30-inch conveyance pipeline, and
- Groundwater treatment plant.

The approximate locations of these facilities are displayed in Figure 4C.16-1.

Cost estimates are developed in accordance with the methodology for regional planning studies (Appendix A). Wells located in the Wells Ranch well field are assumed to be 800 feet deep, similar to nearby existing wells. Wells are assumed to have 500 gpm production capacity, consistent with estimates produced by R. W. Harden & Associates for BMWD, and with existing GCUWCD well permits held by BMWD. A conceptual pipeline alignment has been identified, and a transmission pipeline diameter of 30 inches is estimated to be appropriate. Costs for acquiring groundwater leases, annual lease payments, and anticipated third party mitigation activities to compensate for lowered water levels in existing wells are included to be consistent with other water management strategies. Based on these assumptions, and on an assumed yield of 3,400 acft/yr, it is estimated that the water obtained through the Wells Ranch Project will have a unit cost of $690/acft/yr, or $2.12 per 1,000 gallons (Table 4C.16-4).

4C.16.5 Implementation Issues

Implementation of the Wells Ranch Project could involve limited conflicts with other water management strategies under consideration, including Regional Carrizo for Bexar County, Hays/Caldwell Carrizo project, and/or SSLGC Project Expansion, since each of these will be operating within common groundwater conservation districts.

Table 4C.16-4.
Cost Estimate Summary
Wells Ranch Project
Second Quarter 2002 Prices

Item	***Estimated Costs for Facilities***
Capital Costs	
Shared Pump Station at Well Field (38% of 12.4 MGD)[1]	$1,014,000
Shared Transmission Pipeline (38% of 30 in dia., 30 miles)[1]	$5,927,000
Shared Well Field (38% of 18-500 GPM Wells)[1]	$3,650,000
Shared Treatment Plant at Well Field (38% of 12.4 MGD)[1]	$3,386,000
Total Capital Cost	**$13,977,000**
Engineering, Legal Costs and Contingencies	$4,596,000
Environmental & Archaeology Studies and Mitigation	$375,000
Groundwater Lease Acquisition	$550,000
Mitigation Reserve for Impacts to Local Wells	$1,071,000
Land Acquisition and Surveying (131 acres)	$411,000
Interest During Construction (1 years)	$775,000
Total Project Cost	**$21,755,000**
Annual Costs	
Debt Service (6 percent, 30 years)	$1,463,000
Operation and Maintenance	
Wells, Pipeline, Pumps	$121,000
Water Treatment Plant	$405,000
Pumping Energy Costs (2,403,587 kW-hr @ 0.06 $/kW-hr)	$144,000
Purchase of Water (3,400 acft/yr @ 62.85 $/acft)	$214,000
Total Annual Cost	**$2,347,000**
Available Project Yield (acft/yr)	3,400
Annual Cost of Water ($ per acft)	$690
Annual Cost of Water ($ per 1,000 gallons)	$2.12

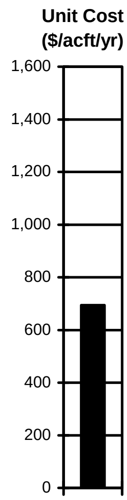
[1] Costs shown for shared facilities are about 38 percent (3,400 / 9,000) of the overall costs for facilities shared by the Wells Ranch and CRWA Dunlap Projects.

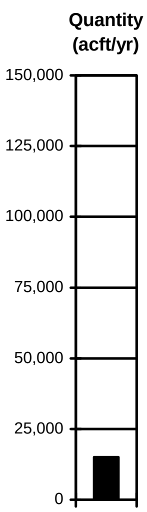
This project was evaluated in conformance with the existing rules of the GCUWCD. Part of the supply developed by this project exceeds the amount of available water identified in the current GCUWCD management plan. The amount of water needed by the project that exceeds the available water in the management plan cannot be implemented unless and until permits are received from the GCUWCD. This project does not cause the GCUWCD management plan to be in conflict with the South Central Texas Regional Water Plan. See Public Comments and SCTRWPG Response Developed through Facilitation for Issue Number 6 in Section 10.2.2.3. Also, as stated previously, production from the Wells Ranch property in Guadalupe County is limited to 1,400 ac-ft/year in accordance with a settlement reached between BMWD and the Guadalupe County GCD.

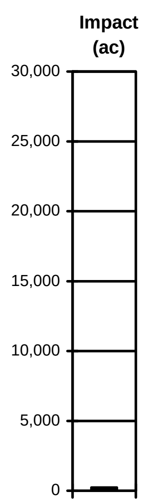
Any project involving production of groundwater from the Carrizo-Wilcox Aquifer in the South Central Texas Water Planning Region must address issues including the following:

- Detailed feasibility evaluation including test drilling and aquifer and water quality testing, followed with more detailed groundwater modeling to confirm results of this preliminary evaluation.
- Impacts on:
  - Endangered and threatened species,
  - Water levels in the aquifer,
  - Baseflow in streams, and
  - Wetlands.
- Competition with others in the area for groundwater.
- Regulations by the Guadalupe County UWCD and GCUWCD, including the renewal of pumping permits at 5-year intervals.
- Water levels did not completely stabilize during the 59-year simulation. If all proposed pumpage continues at 100 percent of planned amounts, water levels could continue to decrease.

2006 South Central Texas Regional Water Plan
Water Management Strategy Summary Sheet







Name: **Hays/Caldwell Carrizo Project**

Description: One well field (10 wells) in Caldwell, Bastrop, Fayette, and possibly Gonzales Counties to deliver a total of about 15,000 acft/year of Carrizo Aquifer groundwater to a consortium of interests including Canyon Regional Water Authority, and the cities of Lockhart, San Marcos, and Kyle. Primary points of delivery are assumed to be the San Marcos WTP and the CRWA Hays/Caldwell WTP. Project includes approximately 37 miles of raw water pipeline, and expansion of water treatment plant capacity to accommodate increased demand.

***Decade Needed*:** 2030-2040

Cost, Quantity of Water, and Land Impacted

Unit Cost of Water:	**694**	**$/acft/yr**	**Treated Water Delivered**
Quantity of Water:	**15,000**	**acft/yr**	**Reliability = Firm**
Land Impacted:	**137**	**acres**	**Pipeline ROW, wellheads, pump stations**

Additional Considerations per Regional Water Planning Guidelines

Environmental Factors:
Pipeline could traverse endangered or threatened species habitat.

Impacts on Water Resources:
Long-term reduction in aquifer levels could affect discharge from small springs and streamflows in outcrop.

Impacts on Agricultural & Natural Resources:
Long-term reduction in aquifer levels could affect discharge from small springs and streamflows in outcrop.

Other Relevant Factors per SCTRWPG:
Lost Pines GCD, Fayette County GCD, Plum Creek Conservation District, and Gonzales County Underground Water Conservation District (GCUWCD) have rules and management plans that need to be considered in project planning. Local GCDs have permitting authority over any export project within their jurisdiction. This project was evaluated in conformance with the existing rules of the Gonzales County UWCD. Part of the supply developed by this project exceeds the amount of available water identified in the current Gonzales County UWCD management plan. The amount of water needed by the project that exceeds the available water in the management plan cannot be implemented unless and until permits are received from the Gonzales County UWCD. This project does not cause the Gonzales UWCD management plan to be in conflict with the South Central Texas Regional Water Plan. See Public Comments and SCTRWPG Responses Developed through Facilitation for Issues 2, 5, and 6 in Section 10.2.2.3.

Comparison of Strategies to Meet Needs:
Low unit cost. Limited conflicts with other recommended water strategies including SSLGC Project Expansion, Wells Ranch Carrizo Project, and/or Regional Carrizo for Bexar County Supply.

Interbasin Transfer Issues: Not applicable.

Third-Party Impacts of Voluntary Transfers:
Mitigation (i.e., lowering of pumps, drilling of new wells, etc.) is required by GCDs for affected third parties.

Regional Efficiency: New supply proximate to water users in Hays and Caldwell Counties.

Water Quality Considerations: Iron and manganese removal may be necessary.

(This page intentionally left blank.)

4C.17 Hays/Caldwell Carrizo Project

4C.17.1 Description of Water Management Strategy

Population growth in portions of Caldwell and Hays Counties that is greater than previously anticipated has resulted in municipal water demands for several water user groups that are significantly greater than previously projected. Numerous entities along the IH35 corridor in Hays and Caldwell Counties have projected needs in the planning period. One proposed project to meet some of these demands is a Carrizo Aquifer well field located in the approximate area of Caldwell, Bastrop, Fayette, and Gonzales Counties (Figure 4C.17-1). The concept that is evaluated in this water management strategy is to begin pumping in year 2030, and to gradually increase pumpage from the well field to rates ranging from 15,000 to 27,000 acft/yr. Groundwater would be collected from the well field and pumped into a raw water conveyance pipeline for delivery points at the San Marcos Water Treatment Plant (WTP) and Hays/Caldwell WTP, both located near the City of San Marcos. Treatment capacity would be upgraded at these locations to accommodate the increased demand.

A feasibility report on this project (and alternatives) was prepared by Lockwood, Andrews, and Newnam (LAN) and Thornhill Group Inc., and submitted to Canyon Regional Water Authority (CRWA) in March 2005. The list of participants in the feasibility study is as follows:

- Canyon Regional Water Authority (CRWA)
- City of Kyle
- City of Lockhart
- City of San Marcos
- County Line WSC
- Creedmoor-Maha WSC
- Crystal Clear WSC
- Martindale WSC
- Maxwell WSC
- McMahan WSC
- Polonia WSC
- Tecon Water Co., LP
- Tri-Community WSC
- Wimberly WSC

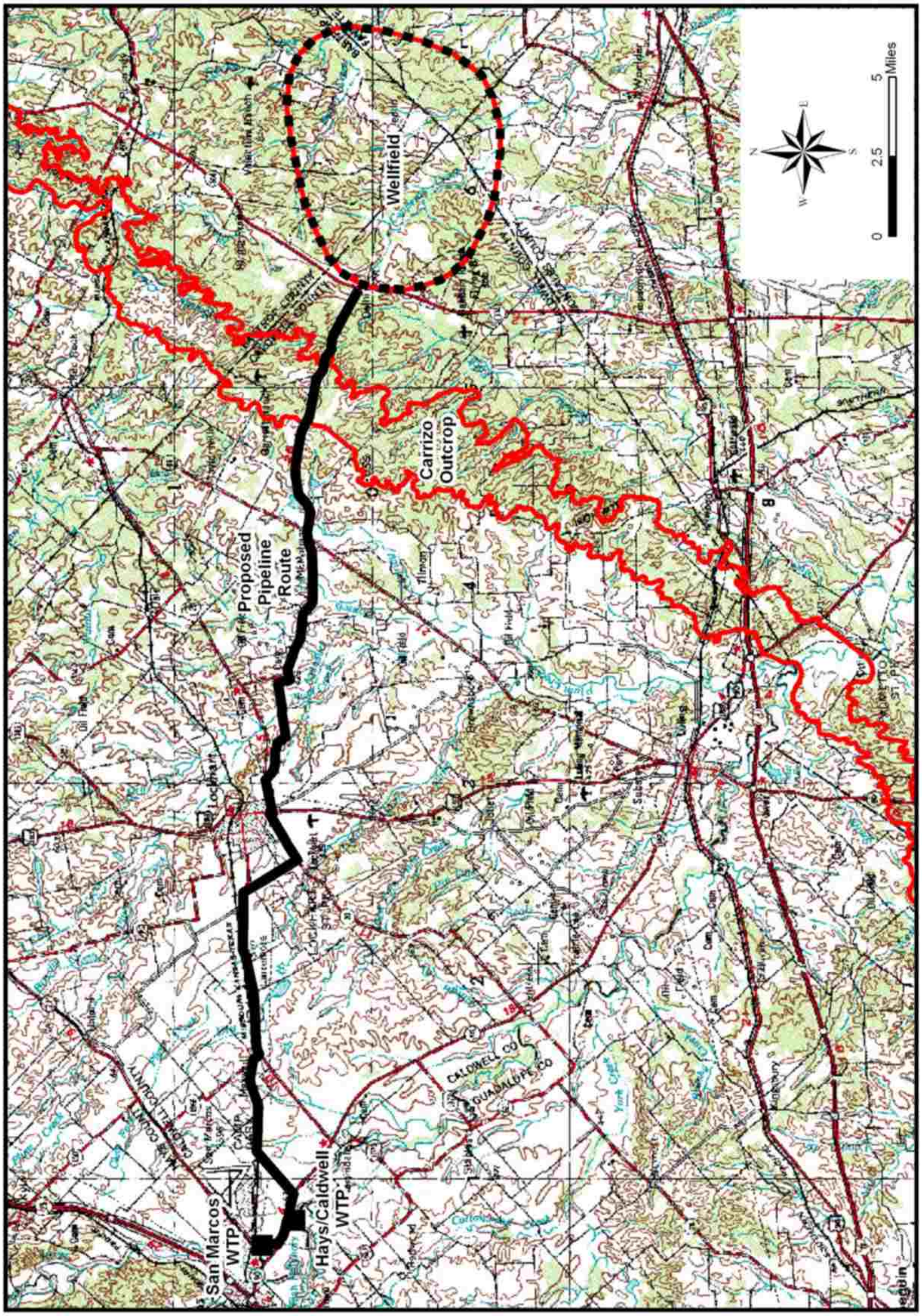


Figure 4C.17-1. Hays/Caldwell Carrizo Project

CRWA acted as the point of contact for the many identified potential participants in this project (hereafter referred to as the Participants). Although not all of these entities have opted to pursue this project as a water management strategy under regional water planning activities, the long list of recipients is illustrative of the fact that many water suppliers in this region face shortages within the planning horizon.

4C.17.2 Available Yield and Projected Drawdown

The Carrizo Aquifer in the vicinity of this project is proven to be a very productive aquifer, with high capacity wells in the confined section of the aquifer routinely capable of producing in excess of 1,000-2,000 gpm. For the purposes of predictive groundwater modeling, two different project yields were evaluated, based on the following input. On October 13, 2004, a coordination meeting was held in the City of Seguin at which the SCTRWPG solicited input from CRWA and the Participants regarding the quantity of groundwater pumpage that they were interested in seeing modeled during the water management strategy evaluation. CRWA responded with three estimates, ranging from a minimum of approximately 27,000 acft/yr in 2060 based on a participant survey, to a maximum estimate of approximately 142,000 acft/yr based on a high growth projection from the State Data Center. For the initial water management strategy evaluation, HDR included pumpage based on the participant survey, with pumpage beginning in 2030 and growing to 27,000 acft/yr by 2060. However, later in the planning process, before the cumulative effects simulations (Section 7.1, Volume I) were run, HDR evaluated the projected needs associated with each Participant and considered available information from the participants as to their interest in pursuing this project. After evaluation of this information, it was estimated that only 15,000 acft/yr is expected to be used by some of the participants by 2060. That is the ultimate productive capacity or yield that was used for the purposes of developing cost estimates for the proposed project and for assessing cumulative effects of this, and other, projects as described in Sections 7.1 and 4C.18.

The predictive simulations that were performed with this project pumpage also included pumpage for the Wells Ranch Carrizo project on the Guadalupe/Gonzales county boundary. Because the Wells Ranch project is located in southern Gonzales County, and is near the outcrop, it is not expected to have a significant impact on drawdowns calculated for the Hays/Caldwell project.

4C.17.2.1 Projected Drawdown

In order to evaluate potential drawdown of the Hays/Caldwell Carrizo project, predictive groundwater modeling simulations were performed with identical pumpage in the common area represented in both models using both the SCCS groundwater model and the SCWQSGAM. Annual Hays/Caldwell project pumpage for these simulations was assumed to be 100 percent of the pumpage displayed in Figure 4C.17-2 and presented in Table 4C.17-1, with a maximum pumpage of 27,000 acft/yr in 2060 associated with this project. As was done in the Regional Carrizo to Bexar County strategy evaluation (Section 4C.14) and the SSLGC Expansion strategy evaluation (Section 4C.15), the Hays/Caldwell Carrizo Project pumpage was added to the pumpage from previous runs, so that pumpage for local supply and other project pumpage would be included in the simulations.

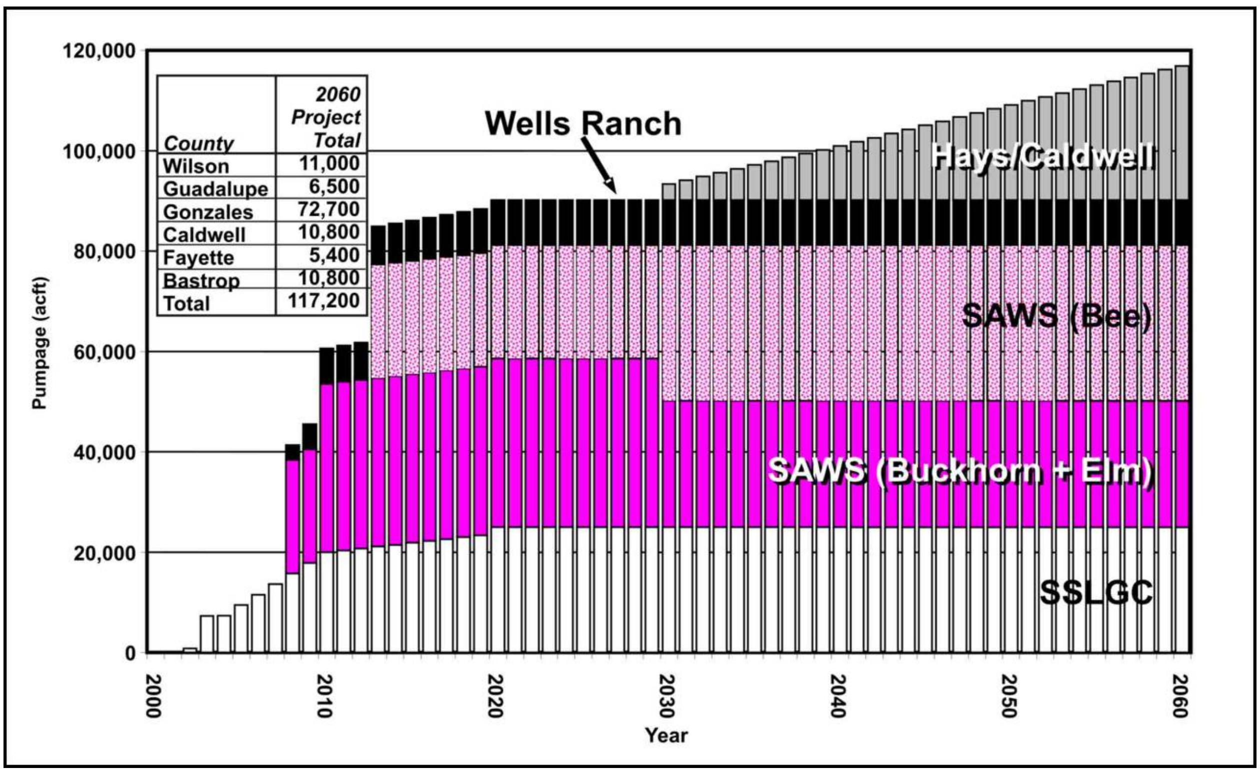


Figure 4C.17-2. Carrizo Groundwater WMS Predictive Pumpage

Table 4C.17-1.
Carrizo Groundwater WMS Predictive Pumpage

Year	SSLGC	SAWS Buckhorn	SAWS Elm	SAWS Bee	Wells Ranch	Hays/ Caldwell	Total
2002	796	0	0	0	0	0	796
2008	11,794	22,600	0	0	3,000	0	37,394
2010	20,000	22,600	11,000	0	7,000	0	60,600
2013	21,500	22,600	11,000	22,600	7,600	0	85,300
2020	25,000	22,600	11,000	22,600	9,000	0	90,200
2030	25,000	16,950	8,250	31,000	9,000	3,168	93,368
2040	25,000	16,950	8,250	31,000	9,000	10,757	100,957
2050	25,000	16,950	8,250	31,000	9,000	18,981	109,181
2060	25,000	16,950	8,250	31,000	9,000	27,000	117,200

The resulting total drawdown from the combined pumpage is presented in Figures 4C.17-3 and 4C.17-4. The SCCS model calculates a maximum 10-foot drawdown contour of 180 feet at the project location in 2060. The SCWQSGAM calculates a maximum drawdown contour of 170 feet at the site.

The drawdown attributable to the Hays/Caldwell project was separated from drawdown due to local pumpage and other projects using the method described in Section 4C.14. The SCCS Model calculates a maximum drawdown of 100 feet attributable to the Hays/Caldwell project (Figure 4C.17-5), while the SCWGAM calculates a maximum drawdown of 70 feet at the project site (Figure 4C.17-6).

In order to examine the change in drawdown with time associated with the project, hydrographs were developed for the 2002 to 2060 simulation period at monitor well locations near the project location in the GCUWCD network. Hydrographs associated with the four predictive scenarios of Local Supply Pumpage, Local Supply + SSLGC, Local Supply + SSLGC + SAWS, and Local Supply + All Projects are displayed in Section 4C.14 in Figures 4C.14-9 (SCCS) and 4C.14-10 (SCWQSGAM).

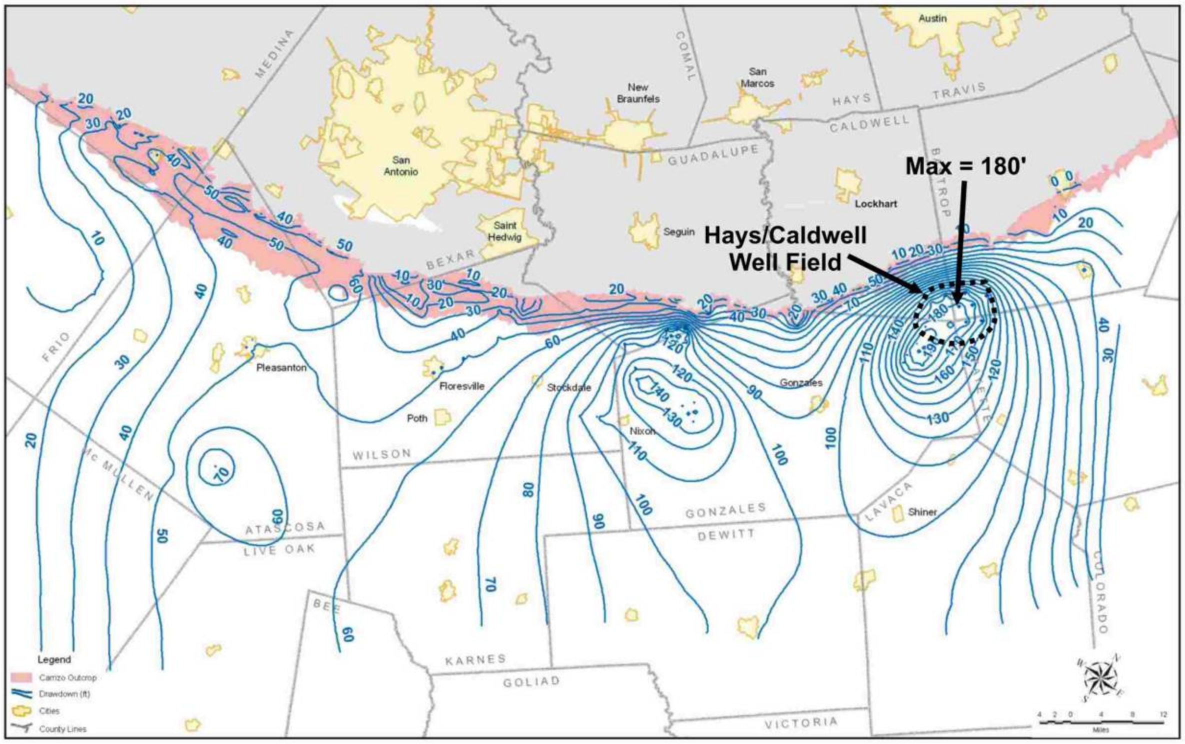


Figure 4C.17-3. SCCS 2002 to 2060 Drawdown: All Projects (with Hays/Caldwell Carrizo Project)

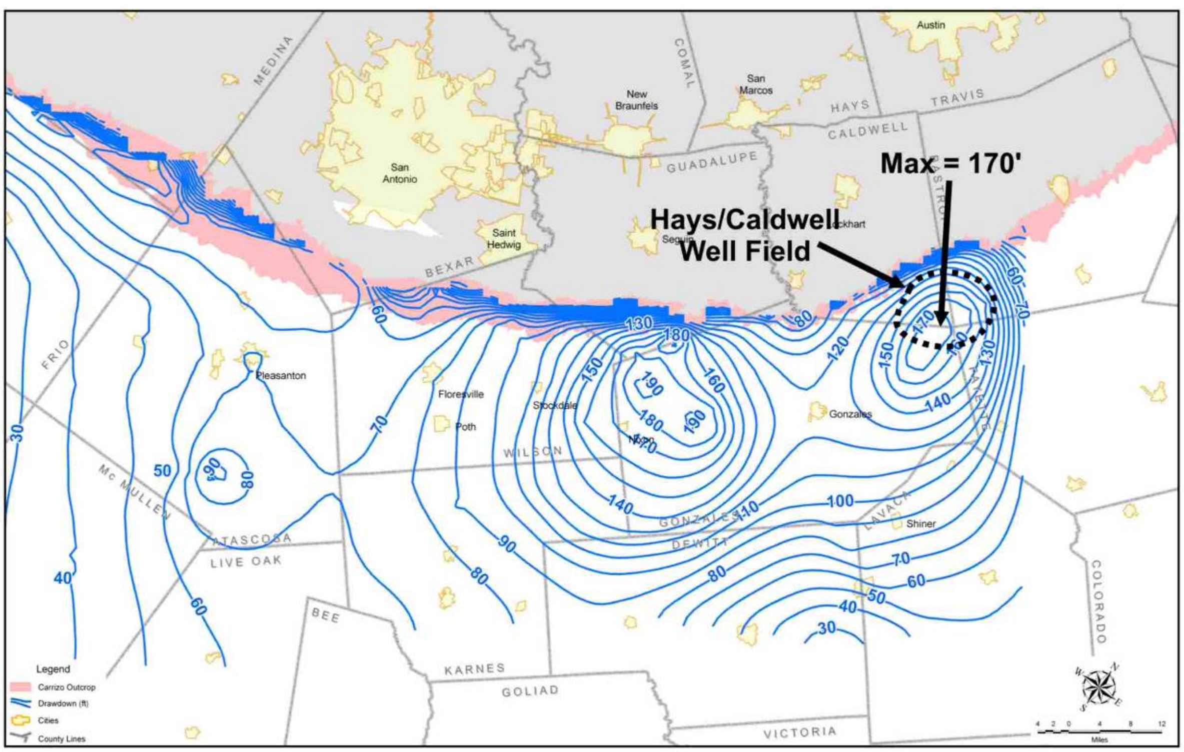


Figure 4C.17-4. SCWQSGAM 2002 to 2060 Drawdown: All Projects (with Hays/Caldwell Carrizo Project)

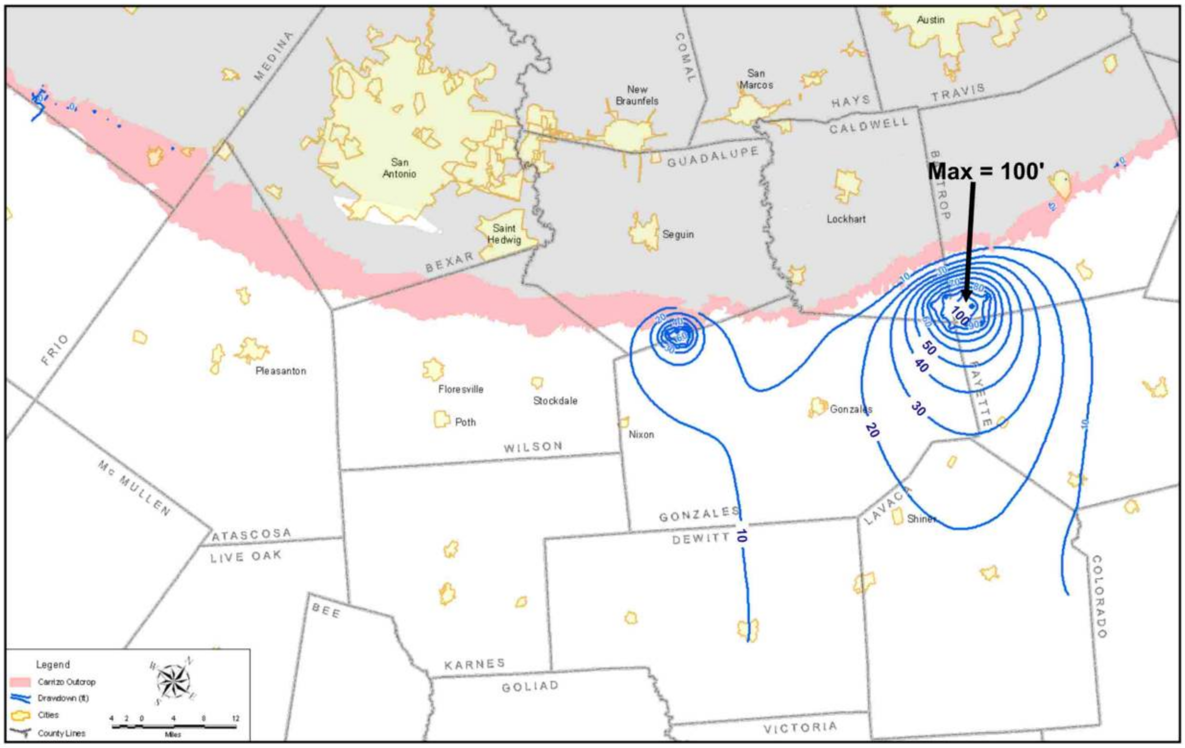


Figure 4C.17-5. SCCS 2002 to 2060 Drawdown Attributable to Hays/Caldwell Carrizo Project (and Wells Ranch Project)

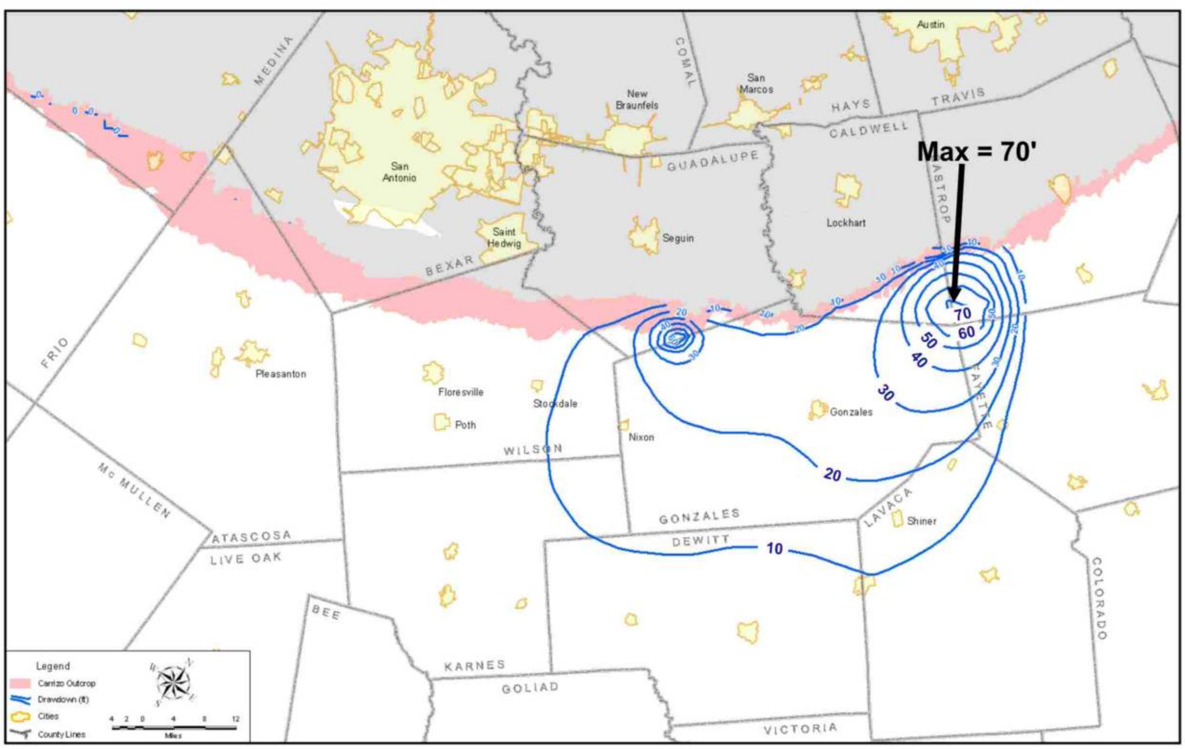


Figure 4C.17-6. SCWQSGAM 2002 to 2060 Drawdown Attributable to Hays/Caldwell Carrizo Project (and Wells Ranch Project)

4C.17.3 Environmental Issues

The Hays/Caldwell Carrizo Project includes a well field located at the intersection of Bastrop, Caldwell, Fayette and Gonzales Counties, which will access the Carrizo Aquifer, and a transmission pipeline for water delivery. Groundwater from this field would be collected and pumped into a pipeline to the San Marcos WTP and Hays/Caldwell WTP, located in San Marcos, Texas. The proposed pipeline route crosses Sandy Fork, and Copperas Creek near the well field, and Plum Creek, a tributary of the San Marcos River, just south of Lockhart in Caldwell County.

The proposed project is located primarily in Caldwell County within the Texas Blackland Prairies ecoregion,[1] in the Blackland Prairie vegetational area of Texas,[2] and in the Texan biotic province.[3] Vegetation types within the project area include crops, native and introduced grasses, brushland and shrubland, small quantities of woodlands, and intermittent river and palustrine scrub/shrub and forested wetlands located primarily near the stream and river crossings. Potential downstream impacts would include modification of the streamflow regime below the well field and a negligible reduction of freshwater inflows to the Guadalupe Estuary.

Plant and animal species listed by USFWS, and TPWD, as endangered or threatened with potential habitat in the Hays/Caldwell Carrizo Project are listed in Table XX. No protected species have been recorded in the study area, although the area may provide potential habitat to endangered or threatened species. Other protected species may use habitats in the area during migration. A survey of the project area may be required prior to well field and pipeline construction to determine whether populations of or potential habitats used by listed species occur in the area to be affected.

The Zone-tailed Hawk (*Buteo albonotatus), a* protected bird species, inhabits arid, open country including deciduous or pine-oak woodlands and may have habitat within the study area. In addition, the proposed pipeline would pass in the vicinity of several mapped rare species: the Guadalupe Bass *(Micropterus treculi),* Sandhill woollywhite (*Hymenopappus carrizoanus*),

---

[1] Omernik, James M., "Ecoregions of the Conterminous United States," Annals of the Association of American Geographers, 77(1), pp. 118-125, 1986.
[2] Gould, F.W., "The Grasses of Texas," Texas A&M University Press, Texas Agricultural Experiment Station, College Station, Texas, 1962.
[3] Blair, W.F., "The Biotic Provinces of Texas, "Tex. J. Sci. 2:93-117, 1950.

Plantainleaf Sunflower (*Helianthus occidentalis*), and Bracted Twistflower *(Streptanthus bracteatus)*.

Several protected species that were not specifically mapped along the proposed well field or pipeline route, but may have essential habitat in the project area include the Timber/Canebrake Rattlesnake, Texas Tortoise, and the Spot-tailed Earless Lizard. The Timber Rattlesnake and Spot-tailed Earless Lizard can be found in woodlands consisting of oak and other hardwoods; the Texas Tortoise prefers open brush with grass understory and usually occupies shallow depressions at the base of a bush or cactus.

Existing regulations would require that habitat studies and surveys for protected species be conducted at the proposed well field sites, construction activity sites, and along any pipeline routes. Monitoring saturated sands of the Carrizo for effects by pumping groundwater may be required to protect the Houston Toad habitat. When potential protected species habitat or other significant resources cannot be avoided, additional studies would be required to evaluate habitat use, permit requirements, and other mitigative measures. Wetland impacts, primarily pipeline stream crossings, can be minimized by right-of-way selection and appropriate construction methods, including erosion controls and revegetation procedures. Compensation for net losses of wetlands would be required where impacts are unavoidable.

Cultural resources protection on public lands in Texas is afforded by the Antiquities Code of Texas (Title 9, Chapter 191, Texas Natural Resource Code of 1977), the National Historic Preservation Act (Pl96-515), and the Archeological and Historic Preservation Act (PL93-291). Based on a review of available records housed at the Texas Archeological Research Laboratory in Austin, at least two cultural resource sites appear to occur within the proposed project area. Table 4C.17-2 lists mapped archeological sites within a one-mile corridor of the proposed project area. Additional cultural resource occurrences within this project area are expected due to the number of stream crossings along the pipeline route, and well field. Because the owner or controller of the project will likely be a political subdivision of the State of Texas (i.e., river authority, municipality, county, etc.), they will be required to coordinate with the Texas Historical Commission prior to project construction. If the project will affect waters of the United States or wetlands, the project sponsor will also be required to coordinate with the U.S. Army Corps of Engineers regarding impacts to cultural resources

Table 4C.17-2.
Previously Recorded Sites within 1-mile Distance from the Proposed Hays/Caldwell Carrizo Project

Sites	41CW67
	41CW19

4C.17.4 Engineering and Costing

Groundwater will be developed by constructing ten new wells, a raw water conveyance pipeline, and expanding existing treatment facilities for chlorine disinfection and iron/manganese removal.

The Hays/Caldwell Carrizo Project is planned to provide an additional 15,000 acft/yr by 2060. The major facilities required for these options are:

- Water Collection and Conveyance System
  - Wells
  - Well field collection pipeline
- 27-inch Conveyance Pipeline (34 miles)
- Water Treatment Plant (Upgrade of Existing Plants).

The approximate locations of these facilities are displayed in Figure 4C.17-1.

Cost estimates were developed in accordance with the methodology for regional planning studies (Appendix A). Wells located in Gonzales County were assumed to be 1200 feet deep, similar to nearby existing wells. A conceptual pipeline layout was developed, and a pipeline diameter of 27 inches was estimated to be appropriate. Costs for leasing property necessary to obtain permits, and for anticipated third party well mitigation activities to compensate for lowered pumping levels in existing wells were included to be consistent with other water management strategies. Based on these assumptions, and on an assumed yield of 15,000 acft/yr, it is estimated that the water obtained through the Hays/Caldwell Carrizo Project will have a unit cost of $694/acft, or $2.13/1,000 gallons (Table 4C.17-3).

The Feasibility Report issued by LAN estimated costs for three different project alternatives that ranged from $1.34/1,000 gallons to $1.55/1,000 gallons for a project that would ultimately deliver 34,700 acft/yr. However, other than savings associated with economy of scale, there are a number of technical assumptions incorporated in the LAN cost estimates that differ from the technical assumptions used in the regional planning methodology (Appendix A).

Table 4C.17-3.
Cost Estimate Summary
Hays/Caldwell Carrizo Project
Second Quarter 2002 Prices

Item	***Estimated Costs for Facilities***
Capital Costs	
Pump Station (14.1 MGD)	$4,008,000
Transmission Pipeline (27 in dia., 34 miles)	$13,949,000
Transmission Pump Station(s)	$3,095,000
Well Fields	$9,878,000
Water Treatment Plant (13.4 MGD)	$9,264,000
Integration	$17,782,000
Total Capital Cost	**$57,976,000**
Engineering, Legal Costs and Contingencies	$24,445,000
Environmental & Archaeology Studies and Mitigation	$5,935,000
Groundwater Lease Acquisition[1]	$1,648,000
Mitigation Reserve for Impacts to Local Wells[1]	$3,203,000
Land Acquisition and Surveying (137 acres)	$1,181,000
Interest During Construction (1 years)	$3,388,000
Total Project Cost	**$97,776,000**
Annual Costs	
Debt Service (6 percent, 30 years)	$6,399,000
Groundwater Lease Payments[1]	$943,000
Operation and Maintenance	
Wells, Pipeline, Pumps	$587,000
Water Treatment Plant	$1,143,000
Pumping Energy Costs (20380892 kW-hr @ 0.06 $/kW-hr)	$1,223,000
District Export Fees ($0.025/1,000 gallons)	$122,000
Total Annual Cost	**$10,417,000**
Available Project Yield (acft/yr)	15,000
Annual Cost of Water ($ per acft)	$694
Annual Cost of Water ($ per 1,000 gallons)	$2.13

1. Groundwater lease and mitigation costs are consistent with detailed costs developed during evaluation of Regional Carrizo to Bexar County WMS (4C.14)

4C.14.5 Implementation Issues

Implementation of the Hays/Caldwell Carrizo Project option could involve limited conflicts with other water management strategies under consideration, including Regional Carrizo to Bexar County, Wells Ranch Carrizo project, and/or Regional Carrizo for SSLGC Expansion, since each of these will be operating all or in part in common groundwater conservation districts.

This project was evaluated in conformance with the existing rules of the Gonzales County UWCD. Part of the supply developed by this project exceeds the amount of available water identified in the current Gonzales County UWCD management plan. The amount of water needed by the project that exceeds the available water in the management plan cannot be implemented unless and until permits are received from the Gonzales County UWCD. This project does not cause the Gonzales UWCD management plan to be in conflict with the South Central Texas Regional Water Plan. See Public Comments and SCTRWPG Response Developed through Facilitation for Issue Number 6 in Section 10.2.2.3.

The development of groundwater in the Carrizo-Wilcox Aquifer in the South Texas Water Planning Region must address several issues. Major issues include:

- Detailed feasibility evaluation including test drilling and aquifer and water quality testing, followed with more detailed groundwater modeling to confirm results of this preliminary evaluation.
- Impact on:
  - Endangered and threatened wildlife species,
  - Water levels in the aquifer,
  - Baseflow in streams, and
  - Wetlands.
- Competition with others in the area for groundwater.
- Regulations by the Evergreen UWCD and Gonzales County UWCD, including the renewal of pumping permits at 5-year intervals.
- Water levels did not completely stabilize during the 59-year simulation and if all proposed pumpage continues at 100 percent of project plans, water levels could continue to decrease before stabilizing.

4C.18 Cumulative Effects of Carrizo Aquifer Development Strategies

4C.18.1 Projected Pumpage

At the direction of the South Central Texas Regional Water Planning Group (SCTRWPG), predictive groundwater simulations for the purpose of evaluating cumulative effects were performed using the South Central Carrizo System (SCCS) groundwater model.[1] Although several successive additive pumpage scenarios were modeled during the Water Management Strategy (WMS) evaluations (Sections 4C.12, 4C.14, 4C.15, 4C.16, 4C.17, and 4C.24), the purpose of those runs was to evaluate individual water management strategies, and not to assess cumulative effects. Pumping levels used in those simulations reflected requests made by the project sponsors, and may not reflect the needs assessments of the water providers involved. For the purposes of the cumulative effects evaluation (Sections 4C.18 and 7.1), needs assessments were performed for each project sponsor, and the predictive pumpage was amended to conform to the planning group's evaluation of projected needs. Therefore, pumpage associated with some of the WMS projects was altered from the quantities represented in the WMS evaluations. Specifically, SSLGC pumpage was altered to slowly grow into an eventual demand of 25,000 acft/yr by 2060, instead of reaching that level of pumpage by 2020 and maintaining it at a constant level thereafter, as was done in the WMS evaluation. Also, the ultimate pumpage associated with the Hays/Caldwell project was decreased from a total of 27,000 acft/yr in 2060 to a total of 15,000 acft/yr in 2060. San Antonio Water System (SAWS) and Bexar Metropolitan Water District (BMWD), Wells Ranch project sponsor, have unmet needs in excess of the amount of pumpage proposed for these projects in Sections 4C.14 and 4C.16, so these pumping quantities were maintained. In addition to pumpage for local supply (including BMWD's plans to produce 4,000 acft/yr from the Stagg Ranch wells in southern Bexar County), Carrizo Aquifer pumpage for the following proposed groundwater export projects was included at the amounts depicted in Figure 4C.18-1 and presented in Table 4C.18-1:

- SSLGC Project (Gonzales and Guadalupe Counties)
- Regional Carrizo for Bexar County (SAWS Project, Wilson and Gonzales Counties)[2]
- Wells Ranch Carrizo Project (Gonzales and Guadalupe Counties)
- Hays/Caldwell Counties Carrizo Project (Caldwell, Bastrop, and Fayette Counties)

[1] For additional pertinent information regarding consideration of water management strategies reliant upon the Carrizo Aquifer, please refer to Issues 2, 5, 6, and 7 in Section 10.2.2.3.

[2] Recent changes in the rules of the Evergreen Underground Water Conservation District may affect estimated costs for this project.

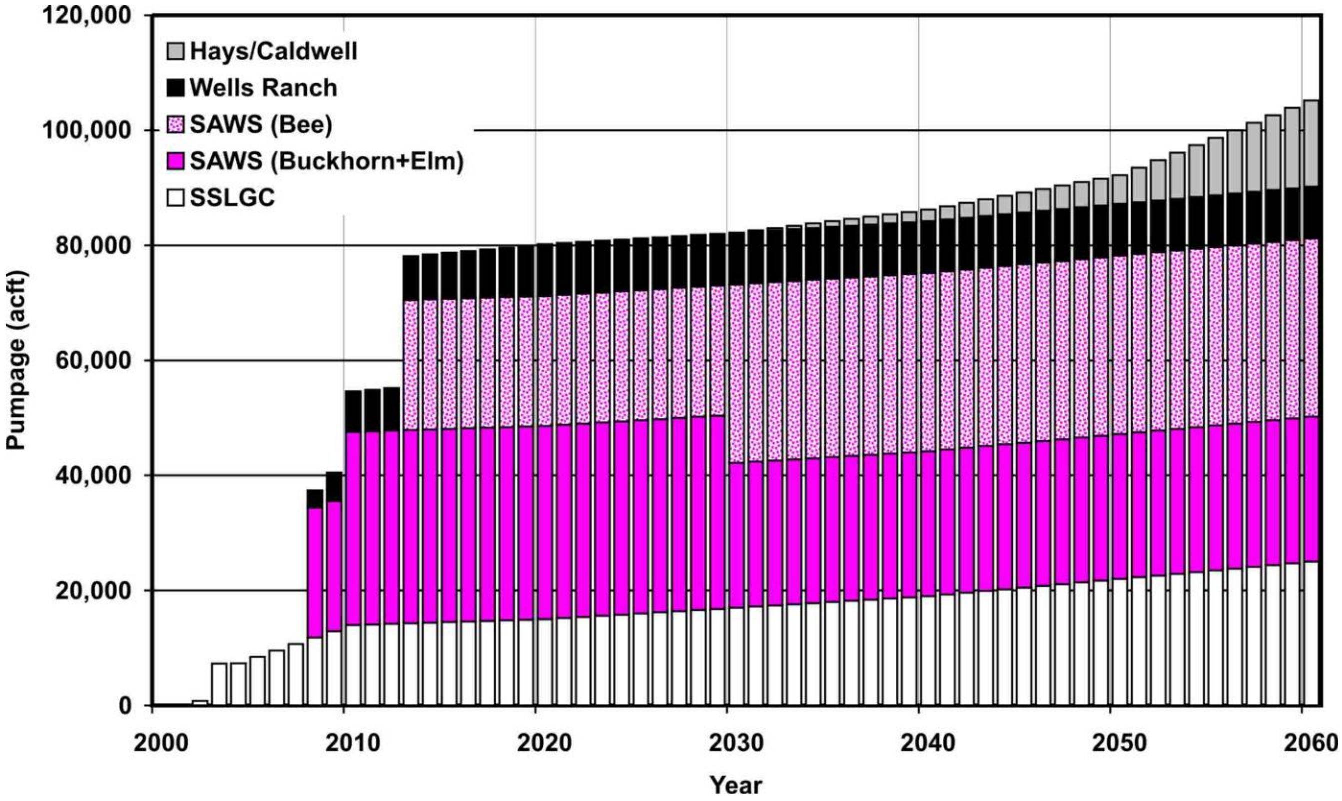


Figure 4C.18-1. SCCS Cumulative Effects Simulation Predictive Groundwater Project Pumpage

Table 4C.18-1. Carrizo Groundwater Cumulative Effects Predictive Pumpage

Year	*SSLGC*	*SAWS Buckhorn*	*SAWS Elm*	*SAWS Bee*	*Wells Ranch*	*Hays/ Caldwell*	*Total*
2002	796	0	0	0	0	0	796
2008	11,794	22,600	0	0	3,000	0	37,394
2010	14,000	22,600	11,000	0	7,000	0	54,600
2013	14,300	22,600	11,000	22,600	7,600	0	78,100
2020	15,000	22,600	11,000	22,600	9,000	0	80,200
2030	17,000	16,950	8,250	31,000	9,000	200	82,400
2040	19,000	16,950	8,250	31,000	9,000	2,000	86,200
2050	22,000	16,950	8,250	31,000	9,000	5,000	92,200
2060	25,000	16,950	8,250	31,000	9,000	15,000	105,200

4C.18.2 Drawdown

The predictive simulations were run for the 2002-2060 time period. Local pumpage and groundwater project pumpage resulted in water level elevations in the Carrizo aquifer and other aquifers being reduced over the time period of the simulation. The resulting Carrizo drawdown over the 59-year simulation period is presented in Figure 4C.18-2.

The total drawdown in the combined area of the SSLGC and SAWS-Buckhorn well fields is over 125 feet by year 2060. The drawdown in the vicinity of the Hays/Caldwell well field is approximately 100 to 125 feet. Drawdown in the area of the SAWS Bee well field is 150 feet, with localized drawdown of 175 feet within the well field.

A time series of the modeled drawdown at key locations throughout the planning period is presented on Figure 4C.18-3.

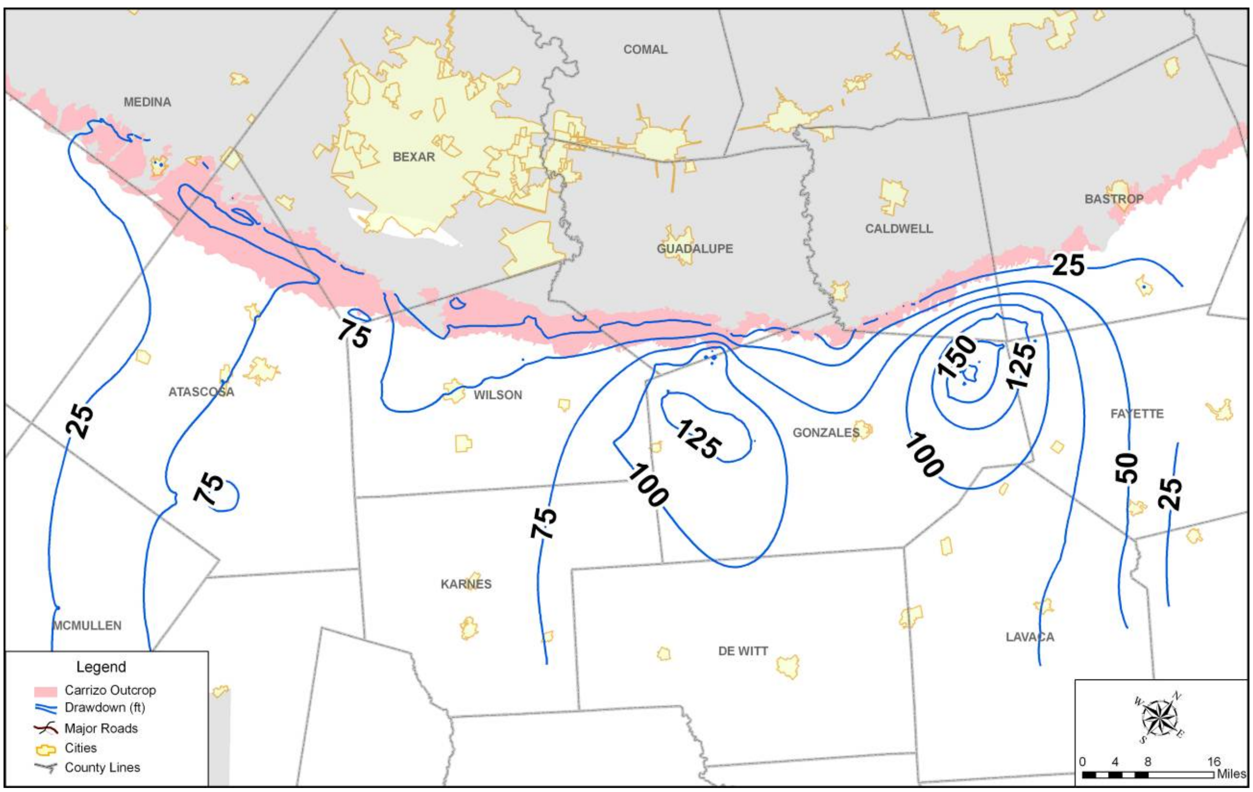


Figure 4C.18-2 SCCS Cumulative Effects Simulation 2002 to 2060 Carrizo Drawdown

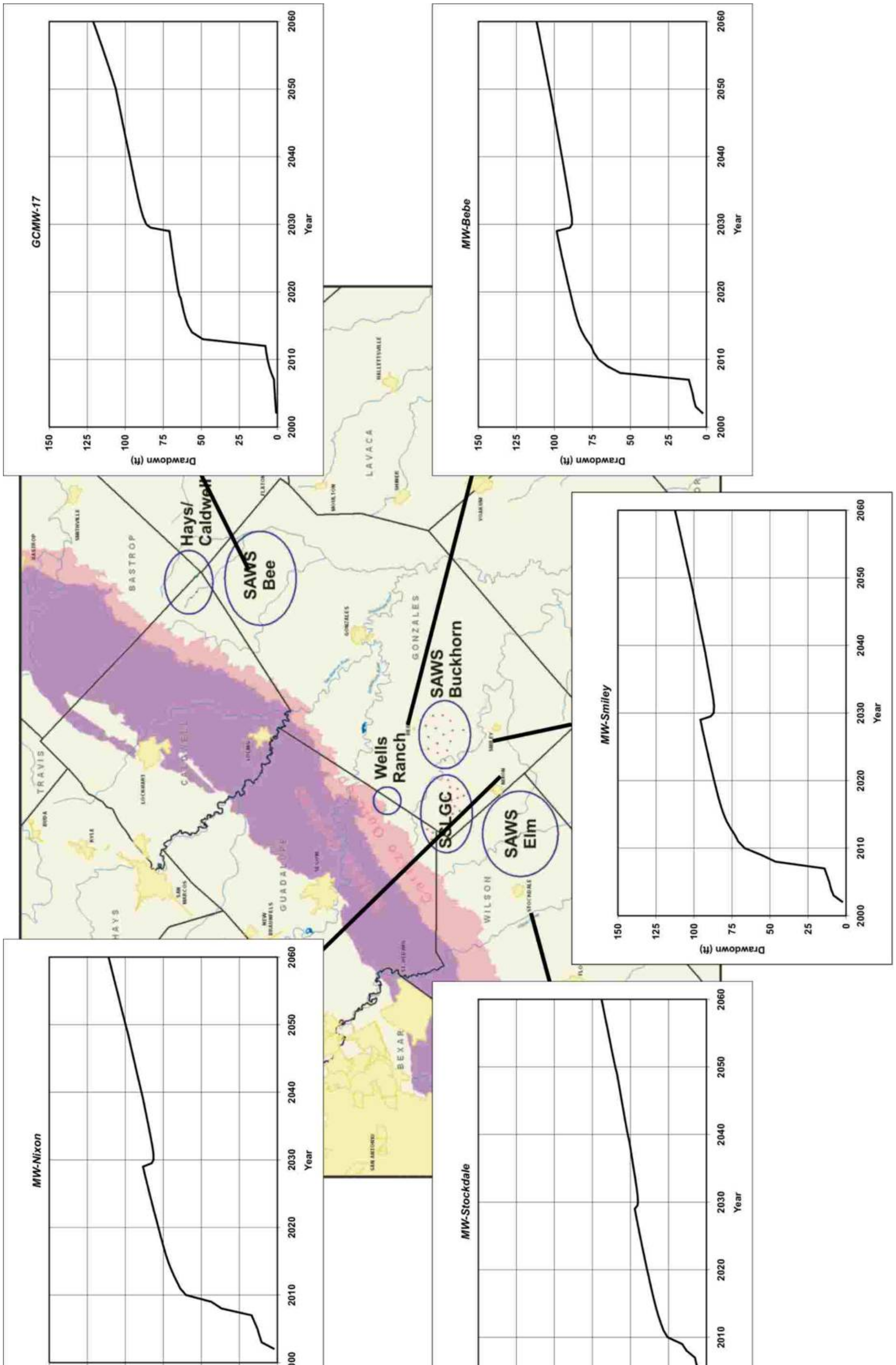


Figure 4C.18-3. SCCS Cumulative Effects Simulation 2002 to 2060 Carrizo Drawdown Hydrographs

4C.18.3 Surface Water/Groundwater Interaction

Due to the effect of vertical communication between adjacent geologic formations, pumping in the Carrizo may also cause some lesser amount of drawdown in adjacent formations such as the Wilcox, Queen City, and Sparta aquifers. Drawdown in the outcrop areas of each aquifer, where hydrologic interaction between the aquifers and the stream channels occurs, results in a reduction of the modeled quantity of surface water/groundwater interaction that naturally occurs between the aquifers and the stream channel. The cumulative effect of drawdown in all modeled aquifers in the SCCS model resulted in a reduction in the amount of discharge from the aquifers to the major stream channels within the model domain. This reduction occurs gradually over time. An example of the modeled change in surface water/groundwater interaction on the Guadalupe River is displayed in Figure 4C.18-4. It should be noted that this reduction does not occur at a single point in space or time, but is a cumulative result from a diffuse source over all the bed and banks of the modeled streams in the watershed. The reduction that is depicted in Figure 4C.18-4 represents the change with time over the entire length of stream channel within the model area. Table 4C.18-2 presents the ultimate reduction in surface water/groundwater interaction at the end of the 59-year simulation period for the major streams in the model area. These reductions, which can be viewed as a change from the average flow conditions without any of the projects, range from 4.9 cfs for the Guadalupe River Basin to 11.7 cfs for the San Antonio River Basin.

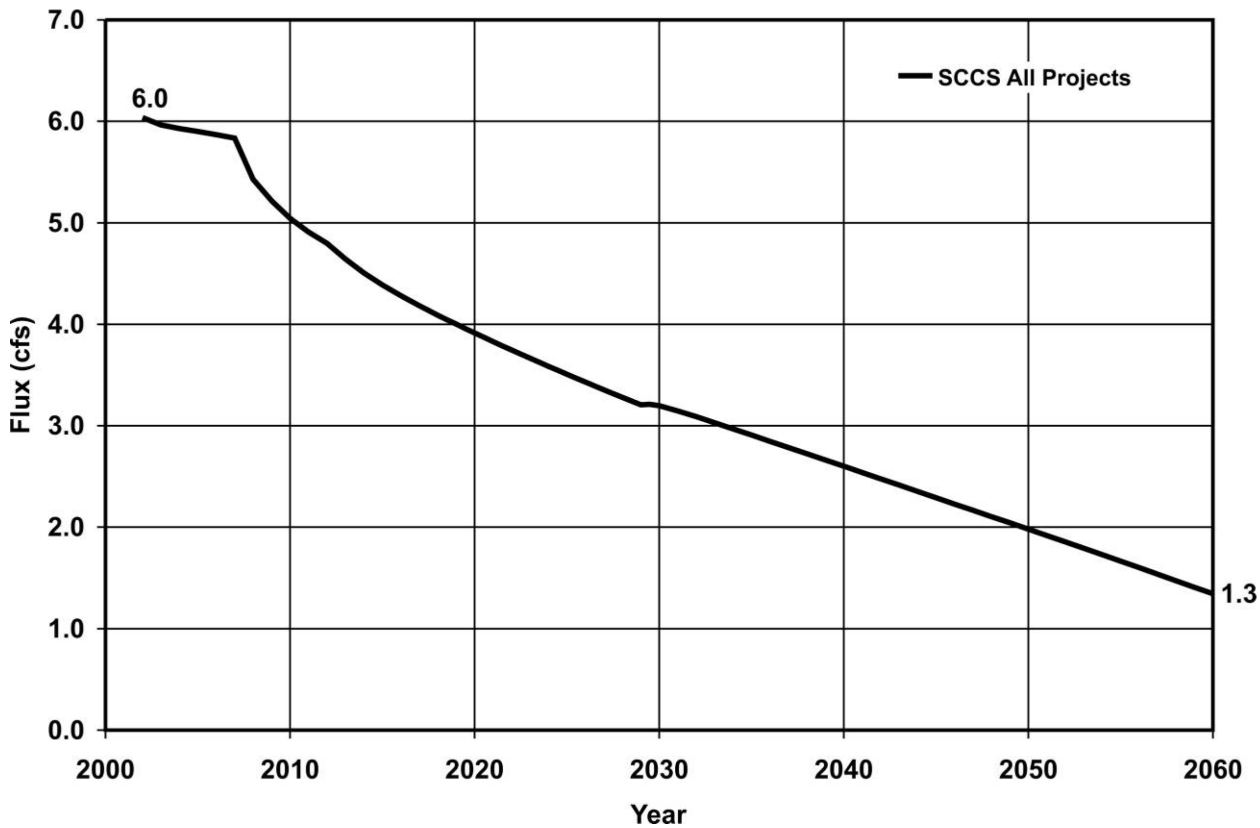


Figure 4C.18-4. SCCS Cumulative Effects Simulation: Predictive Stream/ Aquifer Interaction at Guadalupe River

Table 4C.18-2.
Flux From SCCS Aquifers to Streams (cfs)[1]

	San Antonio River (+Tributaries)	***Cibolo Creek***	***Guadalupe River***	***San Marcos River (+ Tributaries)***
2002	12.3	6.8	6.0	16.3
2060	0.7	0.6	1.3	8.4
Net Change	-11.6	-6.2	-4.7	-7.9

[1]Numbers represent flux from aquifers to stream channels. No initial upstream flow is included, nor adjustments for increased upstream municipal effluent.

4C.19 Cumulative Effects of Gulf Coast Aquifer Development Strategies

4C.19.1 Description of the Central Gulf Coast Aquifer

The Gulf Coast Aquifer underlies all or part of seven counties in the South Central Texas Region and yields moderate to large amounts of fresh to slightly saline water. The Gulf Coast Aquifer extends from Northern Mexico to Florida and covers a large portion of southern Texas, as shown in Figure 4C.19-1. The aquifer is comprised of four water-bearing formations: the Catahoula, Jasper, Evangeline, and Chicot (Figure 4C.19-1). The Evangeline and Chicot Aquifers are the uppermost water-bearing formations and are the most utilized. The Evangeline Aquifer features the highly transmissive Goliad Sands. The Chicot Aquifer is comprised of many different geologic formations, including the Beaumont and Lissie Formations which are predominant in the South Central Texas Region.

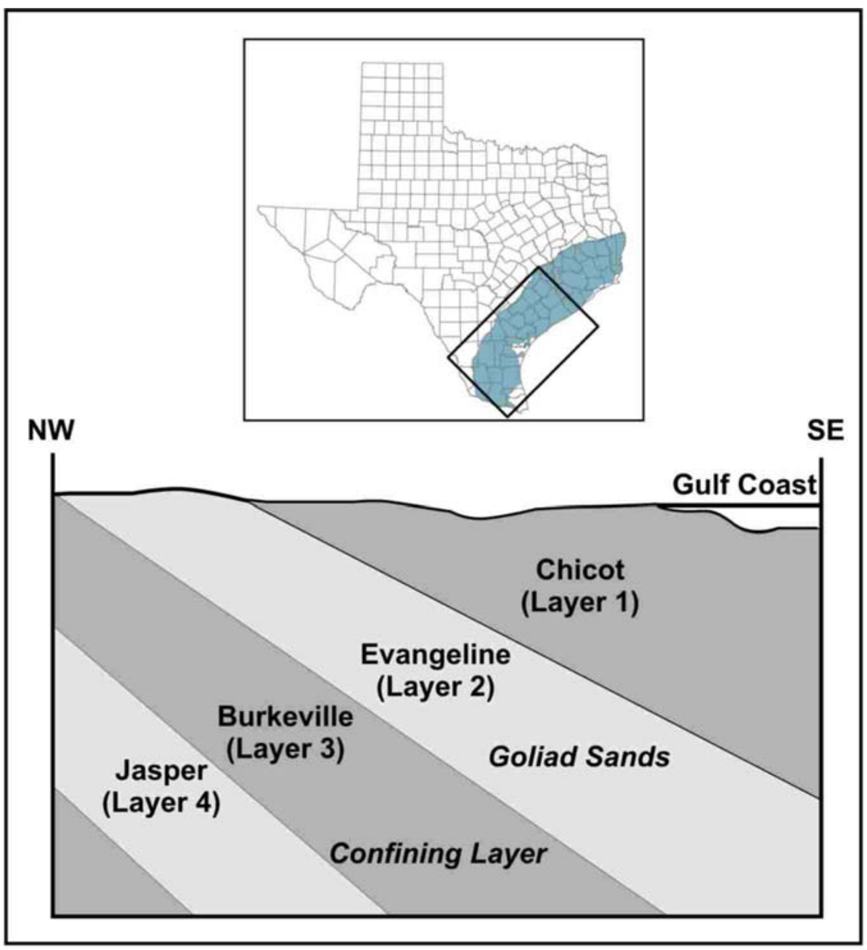


Figure 4C.19-1. Central Gulf Coast Groundwater Availability Model Boundaries and Layers

4C.19.2 Central Gulf Coast Aquifer Ground Water Availability Models

4C.19.2.1 Description of Models

The TWDB sponsored the development of Groundwater Availability Models (GAMs) for all major and minor aquifers in the state of Texas. The GAM that was utilized to support the South Central Texas Regional Water Planning activities is the Central Gulf Coast GAM, which extends from Wharton and Colorado Counties in the northeast to Hidalgo and Starr County in the southwest (Figure 4C.19-1). The model has four layers which thicken and dip toward the Gulf of Mexico. Layer 1 represents the Chicot Aquifer, Layer 2 represents the Evangeline Aquifer, Layer 3 represents the Burkeville confining unit, and Layer 4 represents the Jasper Aquifer. The Catahoula Formation is not represented in the Central Gulf Coast GAM.

Due to technical problems encountered by the TWDB and the GAM contractors during the development of the Central Gulf Coast GAM, there are currently two versions of the model available from TWDB. Each version is appropriate for evaluating predictive scenarios with different purposes. The two versions of the Central Gulf Coast GAM are referred to as the Partially-Penetrating version[1] and the best-calibrated, Fully-Penetrating version.[2] These are the best models currently available to use as tools to calculate the regional effects of local and project pumping on the Gulf Coast Aquifer. These models are essentially identical for most aquifer parameters, with one important difference. They differ in the representation of the hydraulic conductivity (and therefore transmissivity, which equals hydraulic conductivity multiplied by thickness) of Layer 2, the Evangeline Aquifer. The hydraulic conductivity differences between the models are shown in Figure 4C.19-2. During technical meetings between the TWDB and Region L consultants, it was agreed that use of the Partially-Penetrating Model is appropriate when modeling local groundwater demands, because most existing wells in the Evangeline Aquifer are screened only in the upper portion of the aquifer; in other words, the wells only partially penetrate the aquifer, and engage only the upper portion of the aquifer when pumping. It was further agreed that use of the Fully-Penetrating Model is appropriate when modeling major groundwater project demands in which wells are planned to fully penetrate and utilize the entire thickness of the aquifer. Therefore, in order to fulfill the mandate of the RWPG to utilize the best and most appropriate available tools during technical evaluations, local

[1] Chowdhury, A., Wade, S., Mace, R., and Ridgeway, C., *Groundwater Availability of the Central Gulf Coast Aquifer System: Numerical Simulations through 1999*, Texas Water Development Board, September 27, 2004.
[2] Chowdhury, A., *GAM run 05-04*, Texas Water Development Board, January 23, 2005.

groundwater demands in the Central Gulf Coast Aquifer were modeled using the Partially-Penetrating Model, while large project-related groundwater demands were modeled using the Fully-Penetrating Model of the Central Gulf Coast GAM.

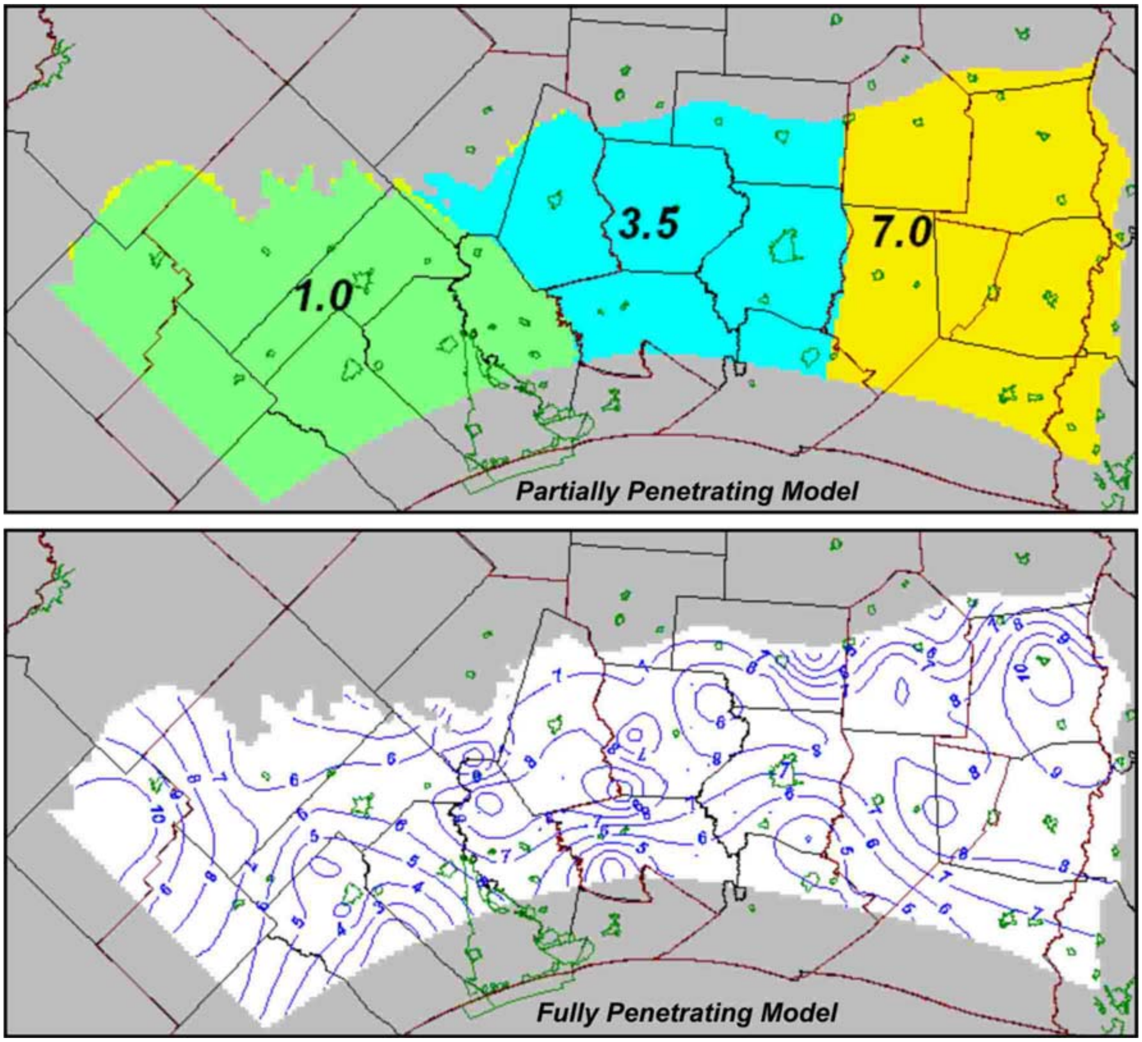


Figure 4C.19-2. Evangeline Aquifer Hydraulic Conductivity in the Partially-Penetrating Model (a) and the Full-Penetrating Model (b) (ft/day)

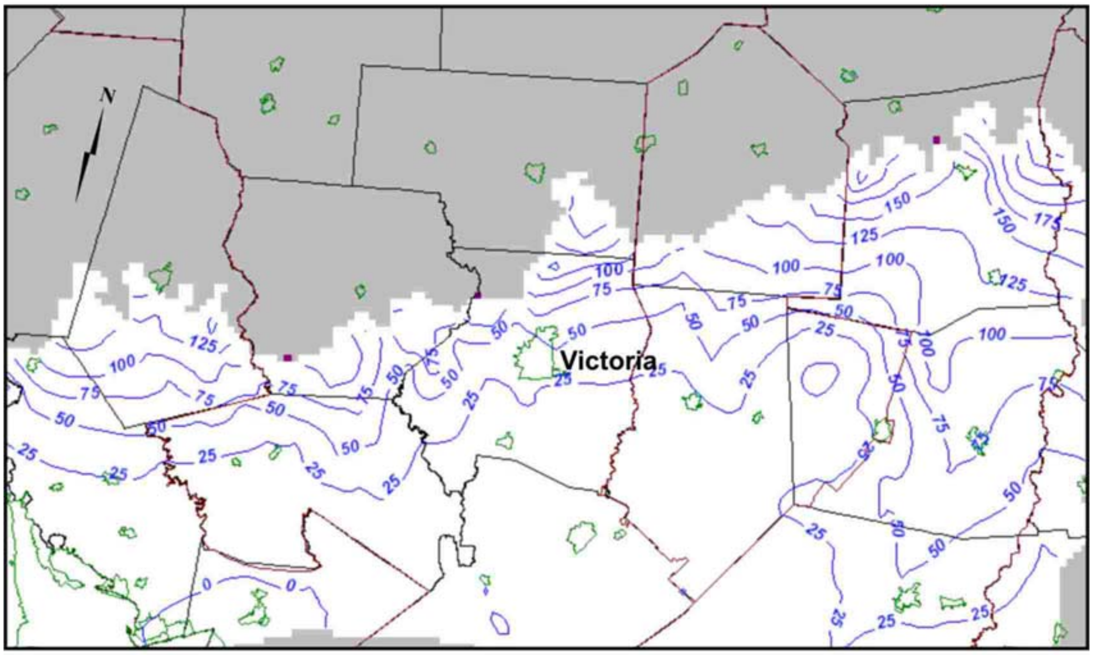
The TWDB released a steady-state (pre-development represented by 1910 to 1940 conditions) and a historical transient (with a calibration period from 1980 to 1999) version of the Central Gulf Coast GAM, both reflective of the partially-penetrating conceptual approach. The historical transient model contains a variable time series of values for recharge, streamflow, pumping, and evapotranspiration. For predictive analysis, a clearer assessment can be made of the effects of pumpage if the other time-variant parameters are held at a constant value. For this reason, the predictive Central Gulf Coast GAM used by HDR to evaluate regional effects of pumping in Region L and Region N for both the Partially-Penetrating version and the Fully-Penetrating version used constant value for these parameters taken from the TWDB steady-state model. The predictive simulations represent the period from 2000 to 2060 with 61 annual stress periods.

The steady-state recharge values were used in the predictive models, with one important exception; the recharge values were modified to include a 6-year drought (simulation years 2017-2022), with drought recharge based on the percentage of reported annual precipitation as a portion of average annual precipitation for the region during the drought of record from 1951 to 1956 (Chowdhury, personal communication, 2005). The storage and specific yield values from the historical transient model were used in the predictive models. The final heads from the TWDB historical transient model, representative of conditions in the year 1999, were used as the initial starting heads for the Partially-Penetrating Model, so that the effects of the historical pumping prior to starting the predictive simulation would be represented. The TWDB steady-state model (with the fully-penetrating hydraulic conductivity) heads were used as the initial starting heads for the Fully-Penetrating Model; thus, these simulations only calculate drawdown estimates specifically associated with the described groundwater development projects. The Chicot Aquifer and Evangeline Aquifer initial heads for both model predictive simulations are shown on Figure 4C.19-3 and Figure 4C.19-4, respectively. It is important to note in Figure 4C.19-3b that a cone of depression already exists in the Evangeline Aquifer near the City of Victoria in 1999 due to historical ground water pumpage, and that calculated predictive drawdown due to local pumpage will be referenced to this starting condition.

4C.19.2.2 Calculating Total Drawdown

Since there are two versions of the Central Gulf Coast GAM (the Partially-Penetrating and Fully-Penetrating) there will be drawdown results and output from both models. In order to calculate total drawdown effects of the aquifer system from both models, the drawdown from each simulation was added together to calculate total drawdown, as shown in Figure 4C.19-5.

Chicot Aquifer



Evangeline Aquifer

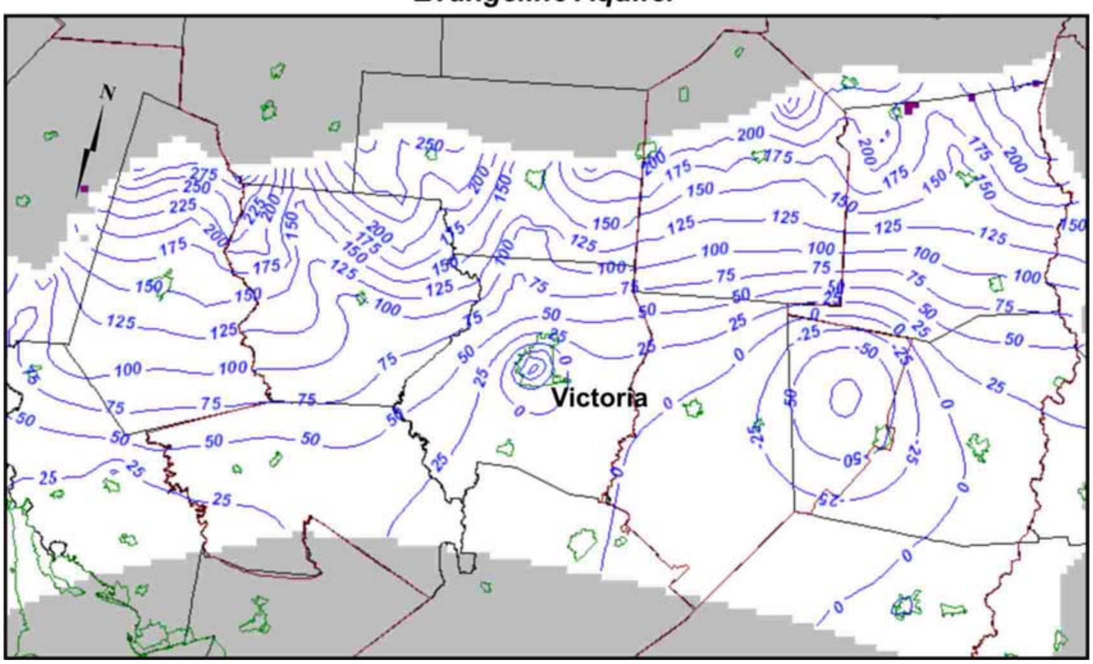
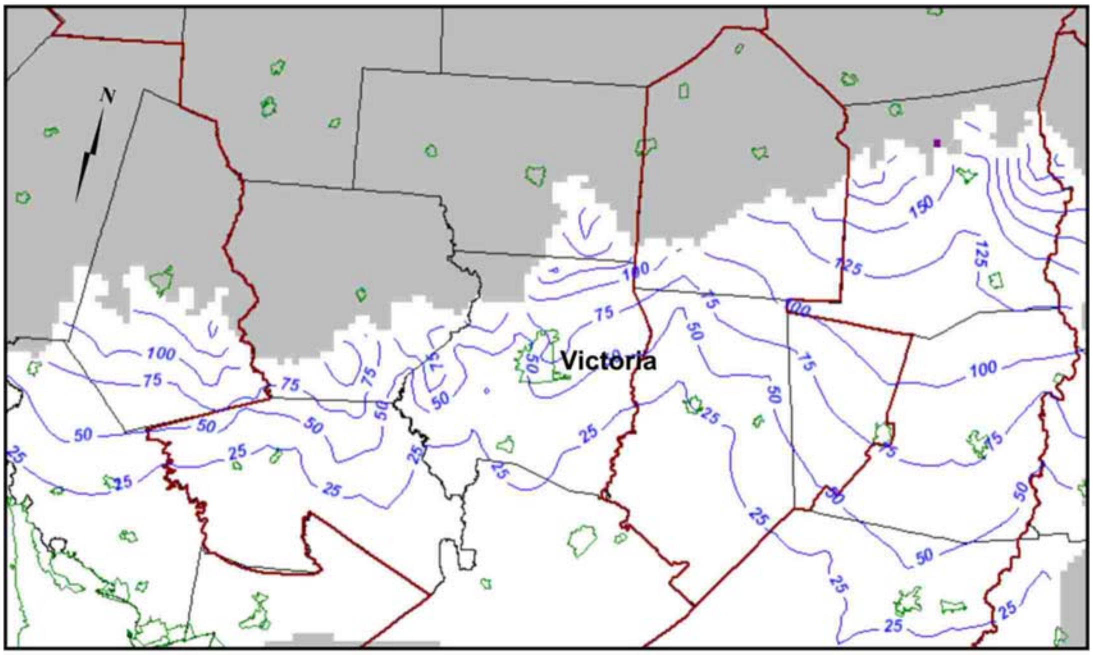


Figure 4C.19-3. Partially-Penetrating Model Initial Heads (feet)

Chicot Aquifer



Evangeline Aquifer

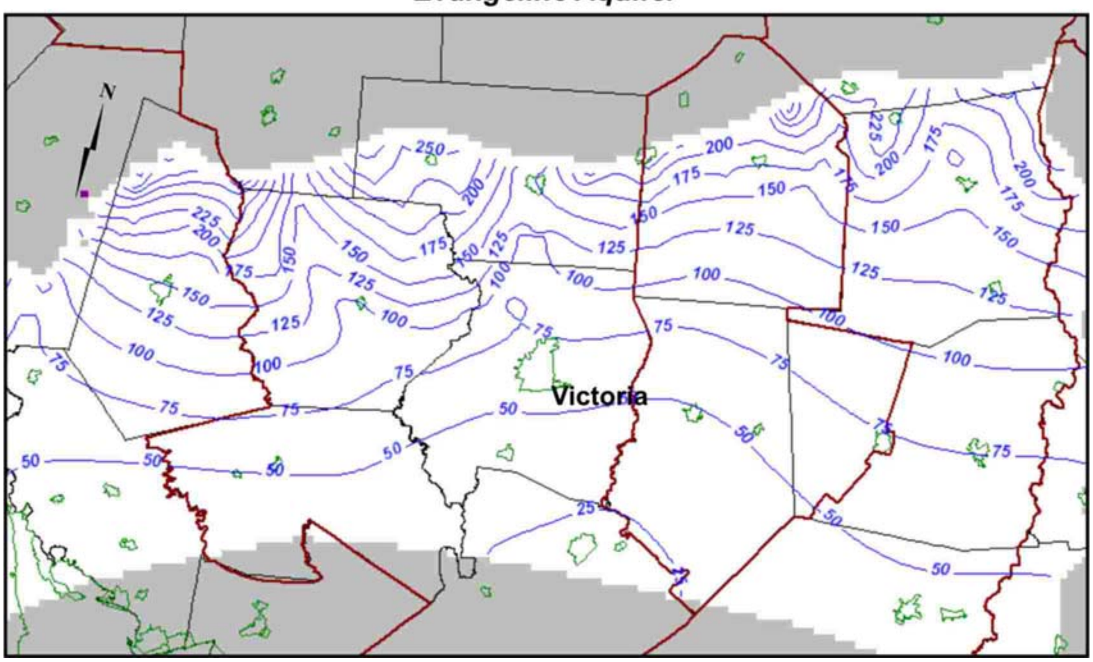


Figure 4C.19-4. Fully-Penetrating Model Initial Heads (feet)

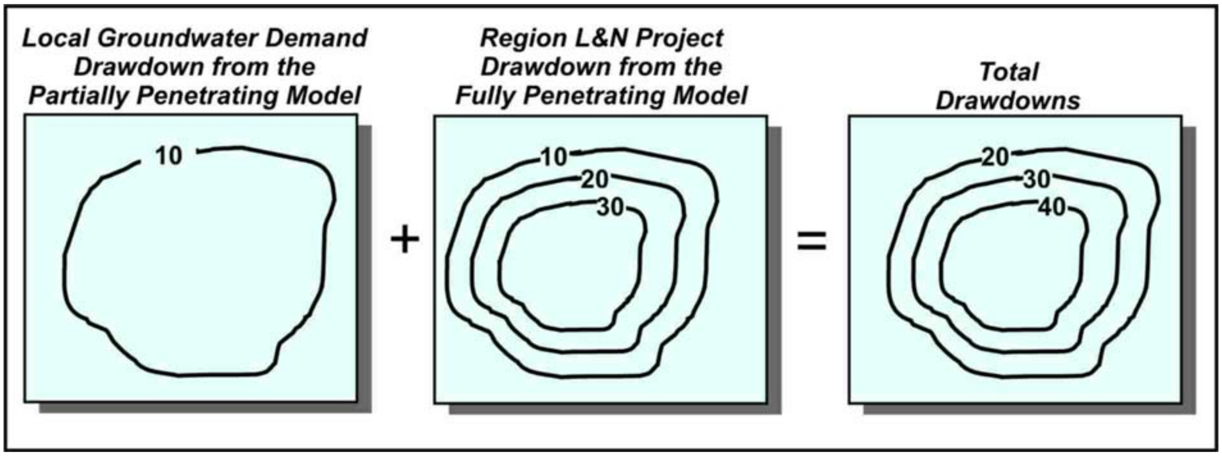


Figure 4C.19-5. Calculating Total Drawdown

4C.19.3 Local Supply Pumpage Predictive Evaluation

4C.19.3.1 Local Supply Predictive Pumping

The Central Gulf Coast GAM covers parts of six water planning regions as shown on Figure 4C.19-6. Predictive pumping data for Regions M, P, K, and H for 2000-2050 were obtained from the TWDB and are consistent with the 2002 Regional Water Plan, which only extends through 2050. Pumpage values for the period 2051-2060 in these regions was held constant at the 2050 value. The 2002 pumping dataset includes water management strategies per the 2002 Regional Water Plan.

Pumping data in Regions N and Region L were updated to reflect the 2006 Regional Water Plan. Region N and Region L developed estimates of total pumpage by county for each of the defined water user groups (municipal, irrigation, manufacturing, steam-electric, livestock, and rural/county-other). The method used to distribute the 2006 Region L and Region N groundwater projection data to cells in the Partially-Penetrating Model included apportioning the pumping between point-source and diffuse use types. Point source use types include pumping that can be attributed to a particular location. The TWDB has documented locations and the utilized aquifers of municipalities, mines, power plants, and manufacturing facilities, using both geographic referencing as well as model cell references. The point source pumping data was distributed to these identified locations and aquifers in the Partially-Penetrating Model.

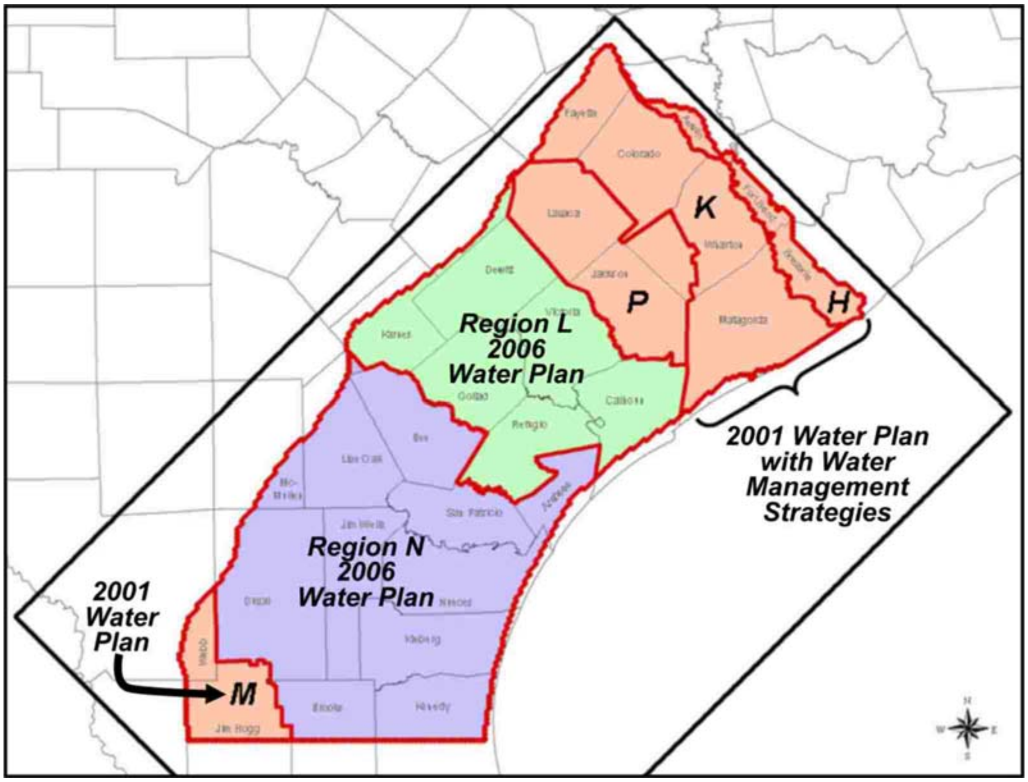


Figure 4C.19-6. Groundwater Pumping Data Sources for the Partially-Penetrating Model

In general, diffuse use types include irrigation, livestock, rural, and any point source pumping with a demand of less than 250 acft/yr. Diffuse pumping model cells were identified in data provided by the TWDB. These cells were used in the historical transient version of the Central Gulf Coast GAM. When developing the predictive pumpage data sets, HDR maintained the relative spatial distribution of diffuse pumpage density within each county that was represented in 1999, the final year of the historical transient simulation.

The predictive annual pumping for each Region L county used to represent local supply pumpage is presented in Table 4C.19-1. Figures 4C.19-7 through 4C.19-11 display the historical (1981-1999) and predictive (2000-2060) annual pumping per county and aquifer for Calhoun, DeWitt, Goliad, Karnes, and Refugio Counties, respectively. With the exception of Victoria County, all other Region L counties predictive groundwater pumping demands exhibit gradual trends that increase or decrease over time.

Table 4C.19-1.
Pumpage for Local Supply
by County (2000 to 2060)
(acft)

Year	*Calhoun*	*DeWitt*	*Goliad*	*Karnes*	*Refugio*	*Victoria (Total)*	*City of Victoria*
2000	1,540	4,616	1,920	3,480	2,358	24,829	11,297
2001	1,528	4,618	1,970	3,459	2,286	20,257	6,290
2002	1,516	4,620	2,020	3,438	2,214	16,077	1,676
2003	1,504	4,622	2,070	3,416	2,141	15,826	990
2004	1,492	4,624	2,120	3,395	2,069	15,270	0
2005	1,480	4,626	2,171	3,374	1,997	20,419	4,714
2006	1,468	4,628	2,221	3,353	1,925	18,023	1,883
2007	1,456	4,630	2,271	3,332	1,853	18,010	1,436
2008	1,444	4,632	2,321	3,310	1,780	18,445	1,436
2009	1,432	4,634	2,371	3,289	1,708	18,880	1,436
2010	1,420	4,636	2,422	3,268	1,636	19,314	1,436
2011	1,409	4,636	2,426	3,279	1,640	19,446	1,625
2012	1,398	4,637	2,430	3,290	1,644	19,199	1,436
2013	1,387	4,637	2,434	3,301	1,648	19,142	1,436
2014	1,376	4,637	2,439	3,312	1,652	21,238	3,590
2015	1,365	4,638	2,443	3,323	1,656	19,027	1,436
2016	1,354	4,638	2,447	3,334	1,659	22,722	5,188
2017	1,343	4,639	2,452	3,344	1,663	25,367	7,891
2018	1,332	4,639	2,456	3,355	1,667	20,511	3,093
2019	1,321	4,640	2,460	3,366	1,671	20,757	3,397
2020	1,310	4,640	2,465	3,377	1,675	26,174	8,871
2021	1,319	4,635	2,468	3,390	1,675	26,672	9,392
2022	1,328	4,630	2,471	3,403	1,674	30,764	13,507
2023	1,336	4,626	2,474	3,415	1,674	19,330	2,097
2024	1,345	4,621	2,477	3,428	1,673	18,647	1,436
2025	1,353	4,616	2,480	3,440	1,673	18,624	1,436
2026	1,362	4,611	2,483	3,453	1,672	18,600	1,436
2027	1,371	4,606	2,486	3,465	1,672	18,577	1,436
2028	1,379	4,601	2,489	3,478	1,671	19,483	2,365

Continued on next page

Table 4C.19-1 Continued

Year	Calhoun	DeWitt	Goliad	Karnes	Refugio	Victoria (Total)	City of Victoria
2029	1,388	4,596	2,492	3,491	1,671	24,248	7,153
2030	1,397	4,591	2,495	3,503	1,670	20,755	3,683
2031	1,408	4,583	2,495	3,512	1,672	18,499	1,436
2032	1,419	4,575	2,495	3,522	1,673	18,489	1,436
2033	1,430	4,566	2,495	3,531	1,675	23,140	6,096
2034	1,441	4,558	2,494	3,540	1,677	18,471	1,436
2035	1,451	4,549	2,494	3,549	1,679	18,461	1,436
2036	1,462	4,541	2,494	3,558	1,680	18,452	1,436
2037	1,473	4,532	2,494	3,568	1,682	20,175	3,169
2038	1,484	4,524	2,494	3,577	1,684	18,433	1,436
2039	1,495	4,515	2,494	3,586	1,685	18,424	1,436
2040	1,506	4,507	2,494	3,595	1,687	18,415	1,436
2041	1,519	4,495	2,493	3,601	1,688	18,425	1,436
2042	1,533	4,483	2,492	3,607	1,690	18,434	1,436
2043	1,546	4,472	2,492	3,613	1,691	18,470	1,462
2044	1,559	4,460	2,491	3,619	1,692	18,474	1,456
2045	1,573	4,448	2,490	3,625	1,694	18,463	1,436
2046	1,586	4,436	2,489	3,631	1,695	18,556	1,519
2047	1,599	4,425	2,489	3,637	1,696	18,483	1,436
2048	1,613	4,413	2,488	3,643	1,697	18,845	1,788
2049	1,626	4,401	2,487	3,649	1,699	18,502	1,436
2050	1,639	4,389	2,487	3,655	1,700	24,331	7,255
2051	1,656	4,383	2,488	3,658	1,699	18,534	1,436
2052	1,673	4,377	2,490	3,660	1,698	18,556	1,436
2053	1,689	4,370	2,491	3,663	1,697	18,633	1,491
2054	1,706	4,364	2,492	3,666	1,696	18,793	1,630
2055	1,722	4,358	2,494	3,669	1,695	23,901	6,716
2056	1,739	4,351	2,495	3,671	1,694	18,643	1,436
2057	1,756	4,345	2,497	3,674	1,693	18,665	1,436
2058	1,772	4,339	2,498	3,677	1,692	18,687	1,436
2059	1,789	4,332	2,500	3,680	1,691	18,708	1,436
2060	1,806	4,326	2,501	3,682	1,690	18,730	1,436

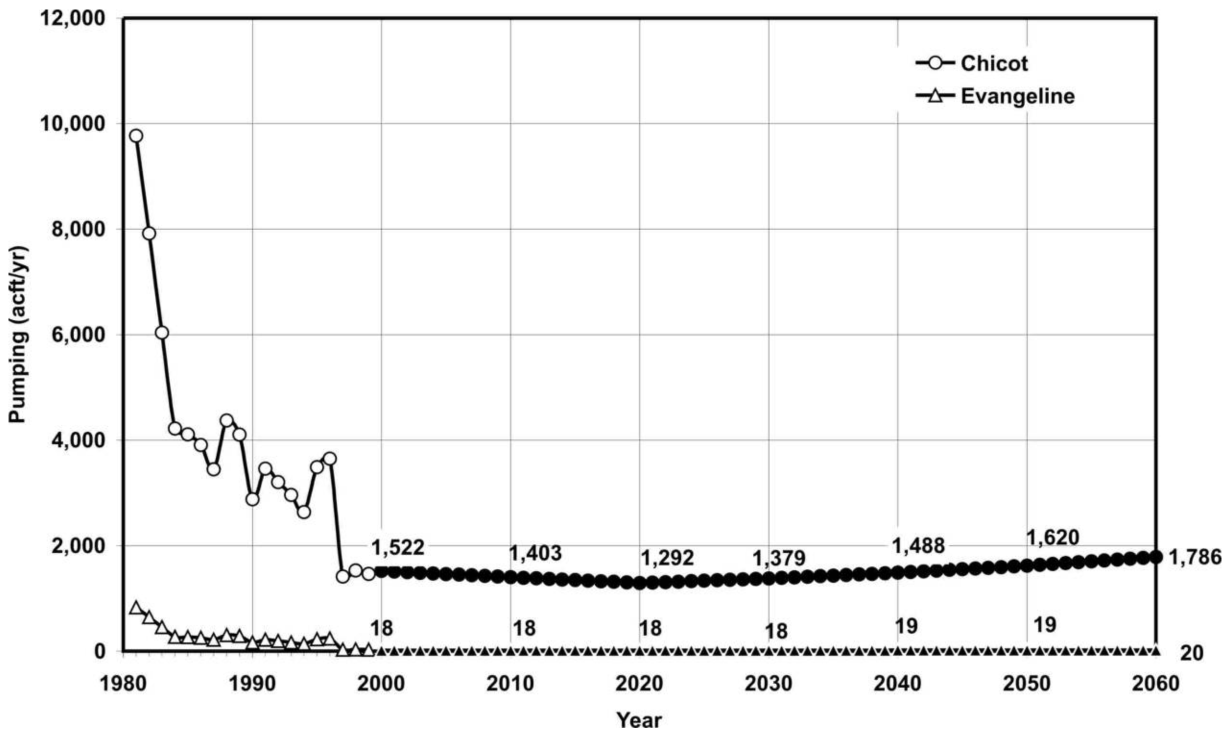


Figure 4C.19-7. Calhoun County Local Supply Historical and Predictive Pumpage by Aquifer

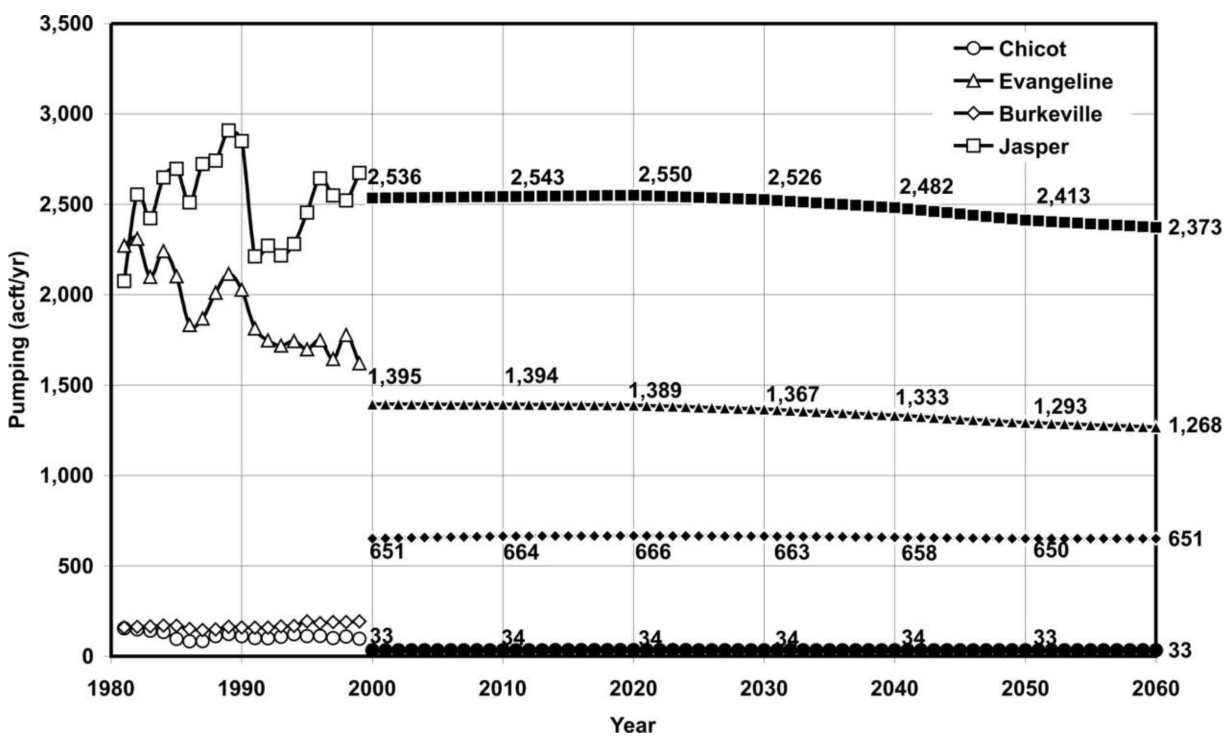


Figure 4C.19-8. DeWitt County Local Supply Historical and Predictive Pumpage by Aquifer

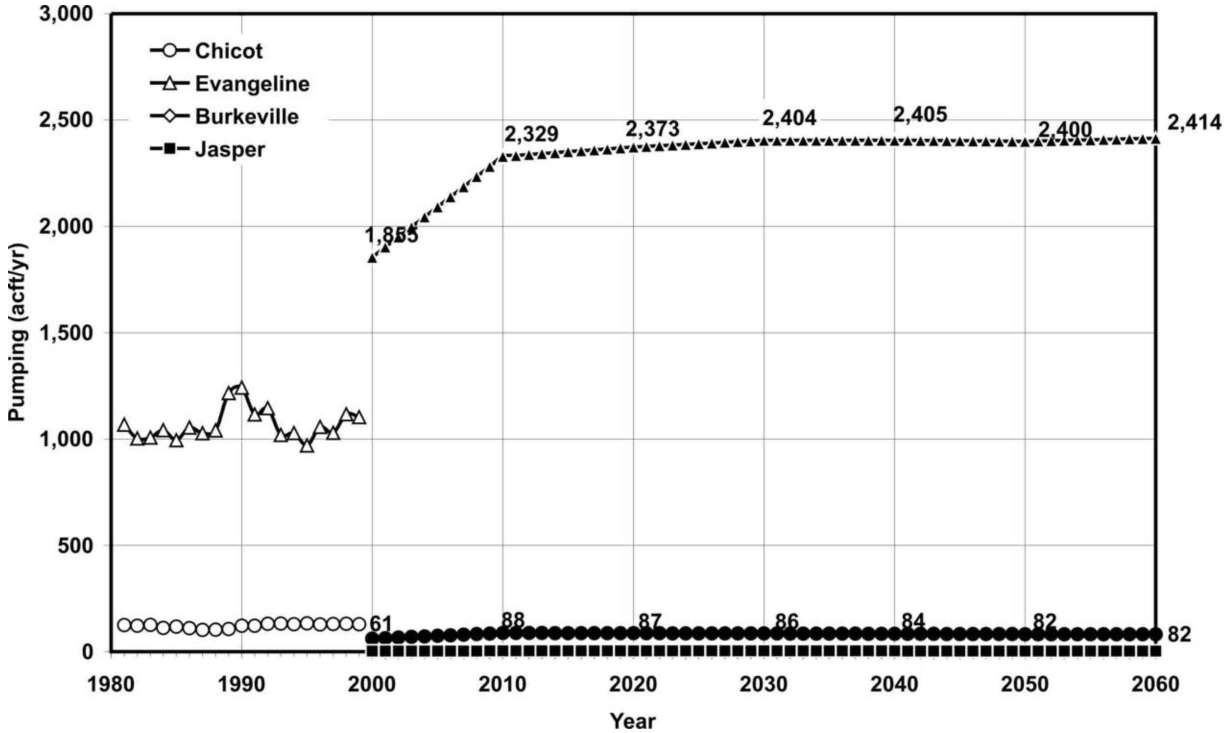


Figure 4C.19-9. Goliad County Local Supply Historical and Predictive Pumpage by Aquifer

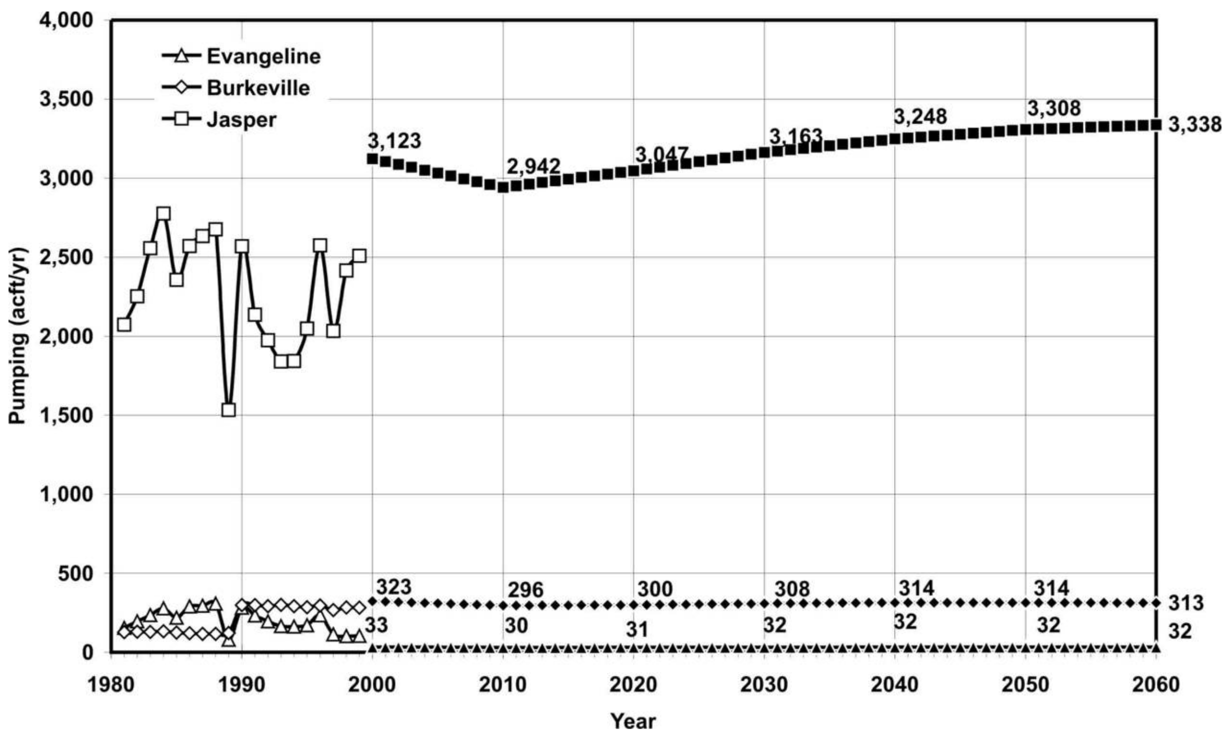


Figure 4C.19-10. Karnes County Local Supply Historical and Predictive Pumpage by Aquifer

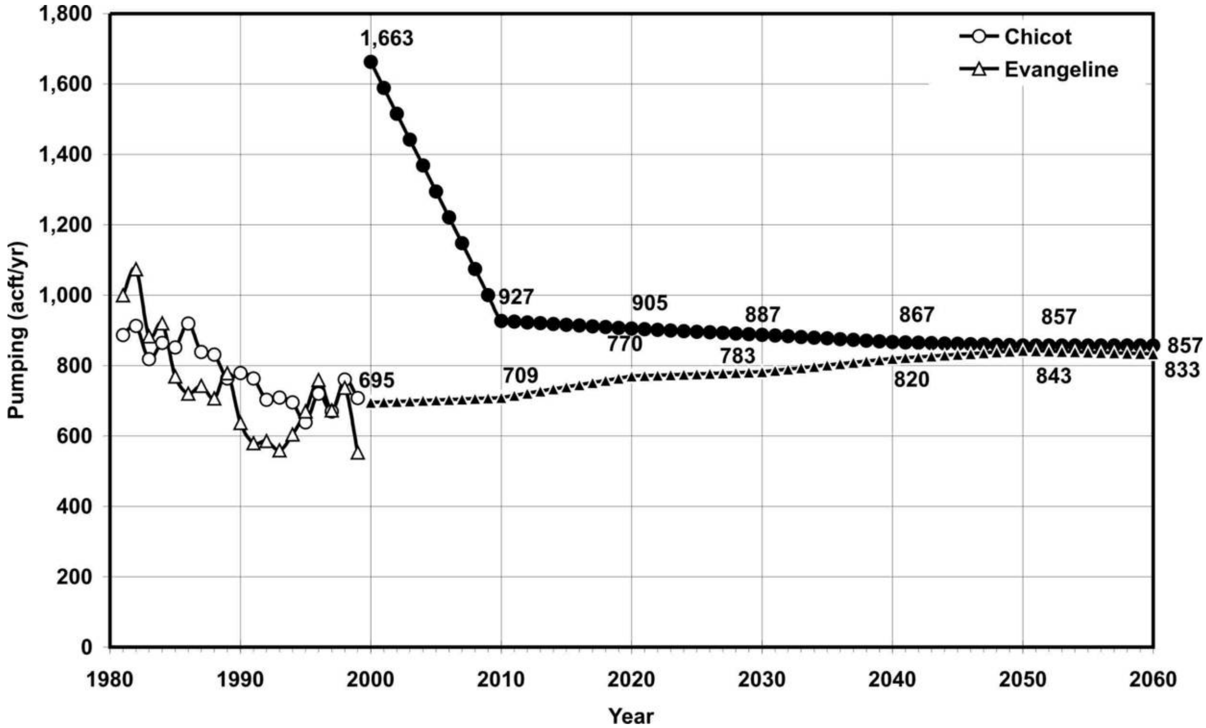


Figure 4C.19-11. Refugio County Local Supply Historical and Predictive Pumpage by Aquifer

Predictive pumpage for Victoria County does not exhibit these gradual trends. The Victoria County historical and predictive annual pumping per aquifer is graphed on Figure 4C.19-12. The fluctuation in the Evangeline Aquifer in Victoria County is attributed to the City of Victoria as shown on Figure 4C.19-13. Historically, the City of Victoria has relied on Gulf Coast Aquifer groundwater for 100% of its supply. However, beginning in 2001, they began integrating surface water sources into their supply, and it is their strategy to utilize surface water as much as possible in the future, using groundwater only as a supplemental source and during times of drought. The City of Victoria has been using both groundwater and surface water since 2001. The model pumping for the City of Victoria reflects actual groundwater use in 2000 to 2004 and projected groundwater use in 2005 to 2060. The projected groundwater use is dependent upon surface water availability calculated using the Guadalupe-San Antonio River Basin Water Availability Model (GSA WAM). When surface water availability is low, the demand for groundwater is high as demonstrated during the 2020 to 2022 model-simulated drought. Consequently, when surface water availability is high, the demand for groundwater is

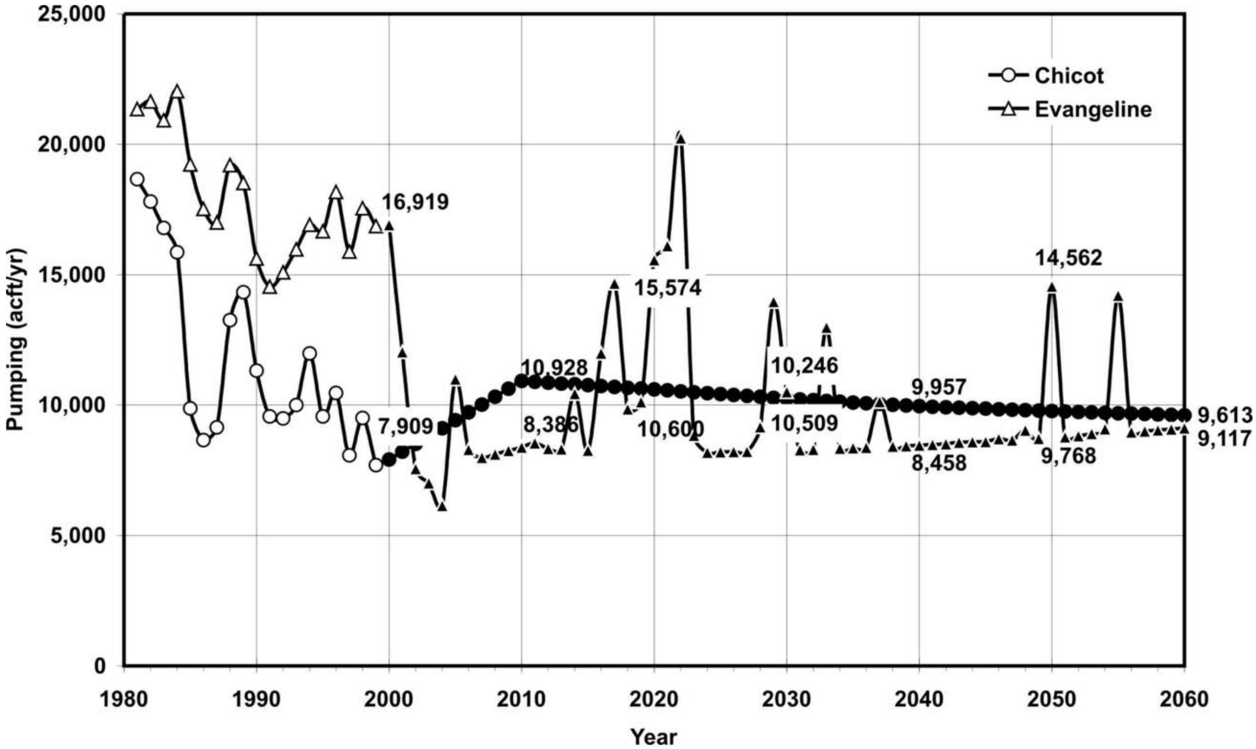


Figure 4C.19-12. Victoria County Local Supply Historical and Predictive Pumping by Aquifer

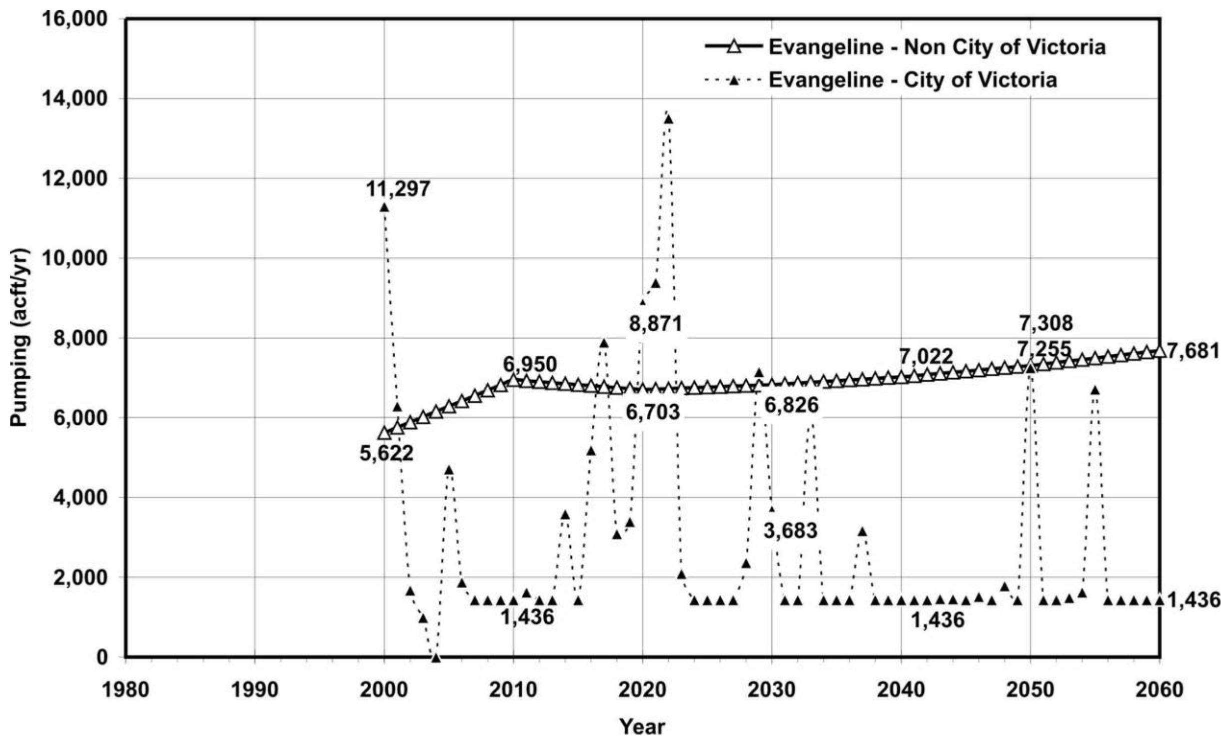


Figure 4C.19-13. Victoria County Predictive Evangeline Pumping

low. Pursuant to discussions with the City of Victoria, the model assumes that a minimum of 10 percent of the city's total water demand will be met with groundwater.

Figures displaying the 2060 local supply pumpage distribution by county and aquifer are presented in Figures 4C.19-14 through 4C.19-17.

4C.19.3.2 Local Supply Pumpage Simulation

Predictive groundwater elevation levels calculated by the Partially-Penetrating Model for the Chicot Aquifer in 2060 using the local supply pumpage estimates are presented in Figure 4C.19-18, and the calculated 60-year predictive drawdown (2000 to 2060), is presented in Figure 4C.19-19. Predictive groundwater elevation levels for the Evangeline Aquifer in 2060 are presented in Figure 4C.19-20 and the calculated 60-year predictive drawdown (2000 to 2060) is presented in Figure 4C.19-21. Drawdown is calculated by subtracting the modeled 2060 groundwater elevations from the initial condition groundwater elevations, (Figure 4C.19-3).

Drawdown Figures 4C.19-19 and 4C.19-21 show that there is -30 feet and -90 feet of drawdown near the City of Victoria in the Chicot Aquifer and Evangeline Aquifers, respectively. This indicates that the water levels have *rebounded* 30 feet and 90 feet in these respective aquifers, as measured from year 2000 conditions. These rising water level elevations are the result of Victoria's projected decreasing reliance on groundwater, resulting in a rebounding of groundwater level during non-drought conditions from the 1999 levels, when a cone of depression had already been established in Victoria. Portions of Goliad and Bee Counties display drawdowns of about 10 feet and 30 feet, respectively, that is not associated with any pumping activity. These localized phenomena appear to be artifacts of non-equilibrium conditions in the initial heads that were obtained from the historical transient simulations, and are not associated with any pumping.

4C.19.4 Groundwater Development Project Predictive Simulation

4C.19.4.1 Groundwater Project Predictive Pumping

In addition to 2006 Region L groundwater projection pumpage to meet local demand, several groundwater export projects have been proposed for the Gulf Coast Aquifer in Region L as well as in the neighboring Coastal Bend Water Planning Region (Region N). These projects

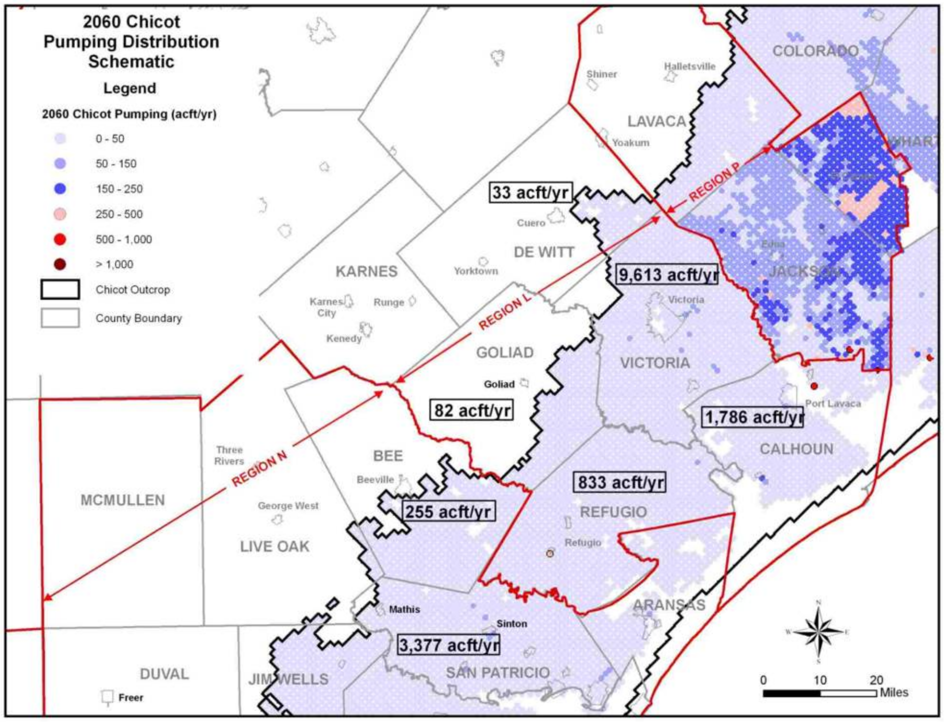


Figure 4C.19-14. Chicot Aquifer 2060 Local Supply Pumping Distribution

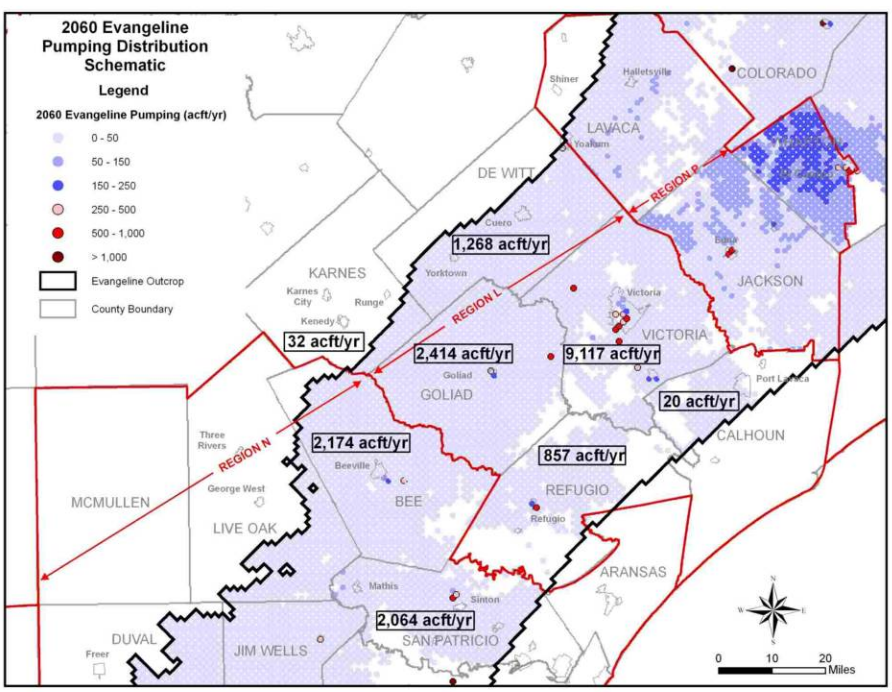


Figure 4C.19-15. Evangeline Aquifer 2060 Local Supply Pumping Distribution

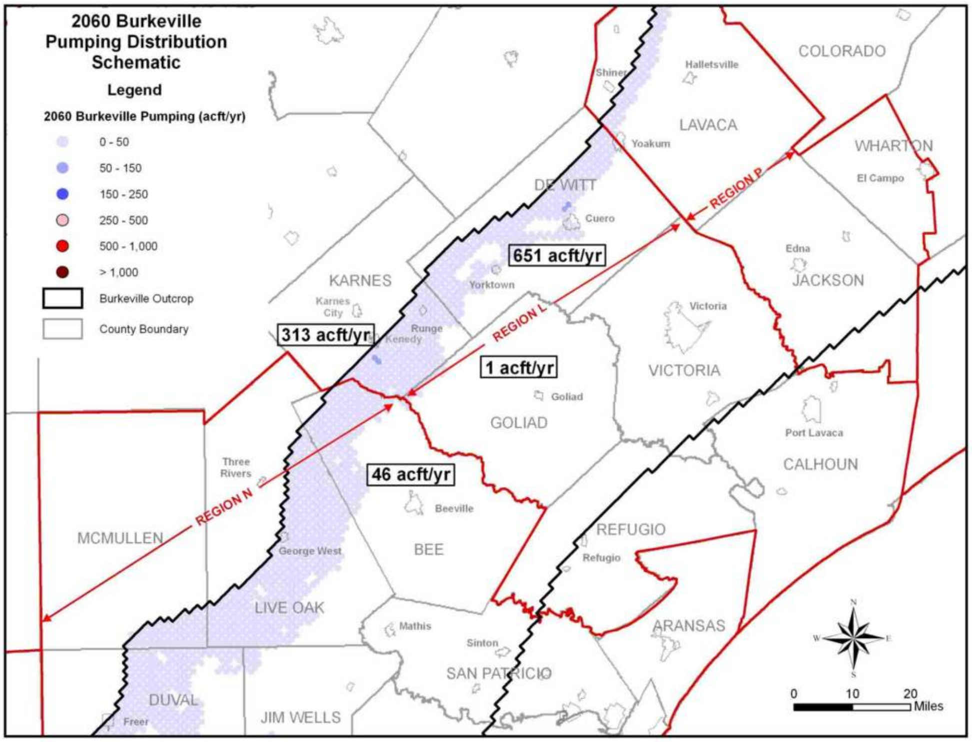


Figure 4C.19-16. Burkeville Aquifer 2060 Local Supply Pumping Distribution

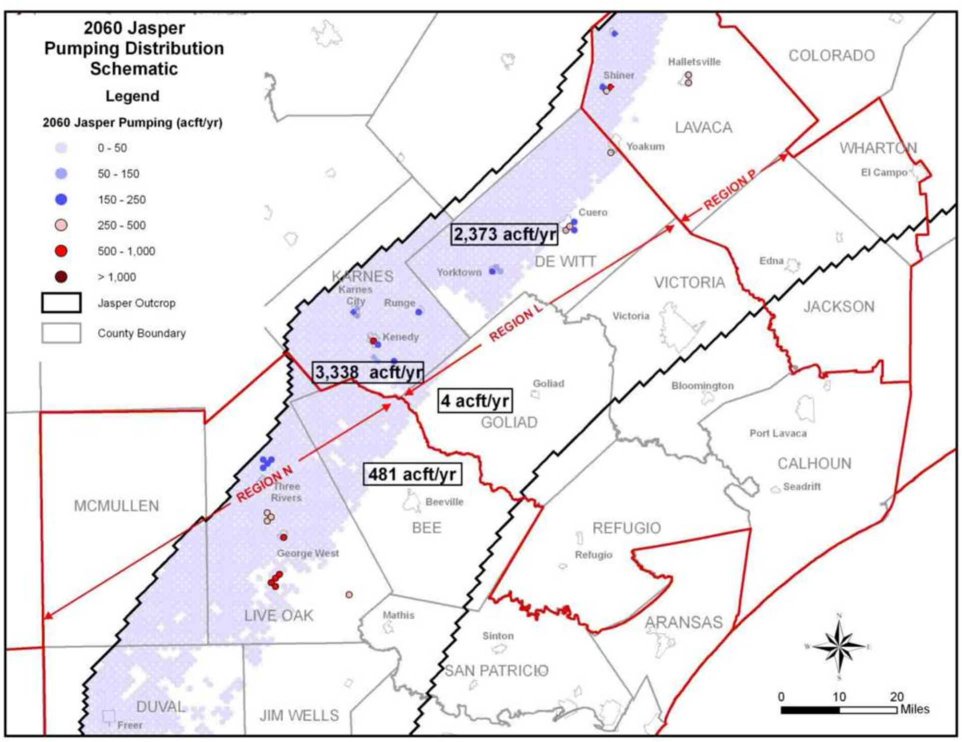


Figure 4C.19-17. Jasper Aquifer 2060 Local Supply Pumping Distribution

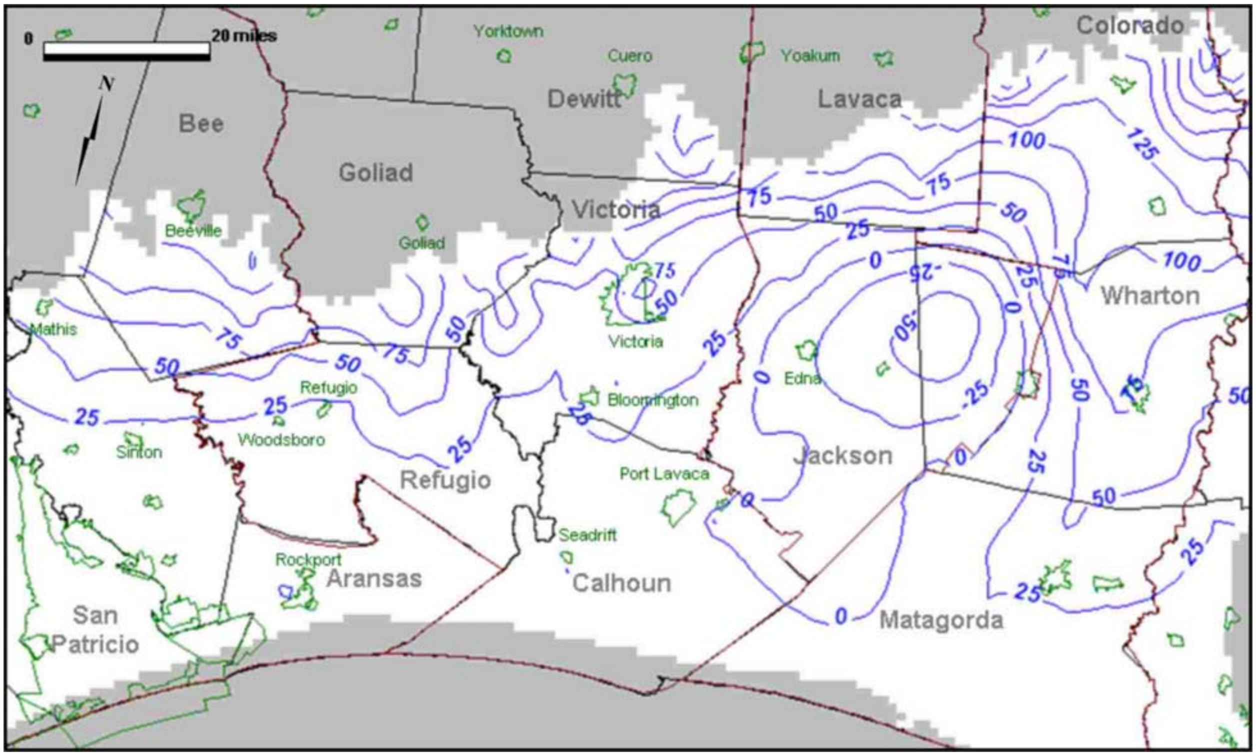


Figure 4C.19-18. Year 2060 Chicot Groundwater Elevation: Local Supply Pumpage

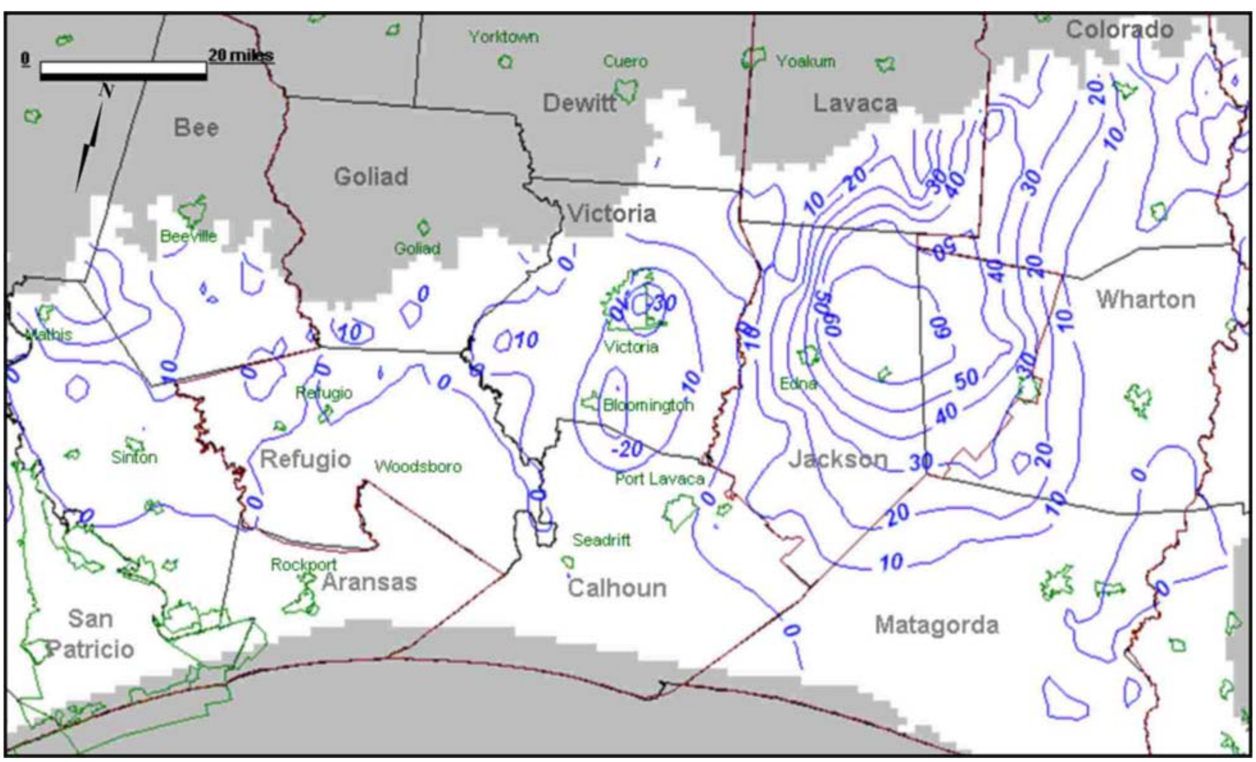


Figure 4C.19-19. 2000-2060 Chicot Drawdown: Local Supply Pumpage

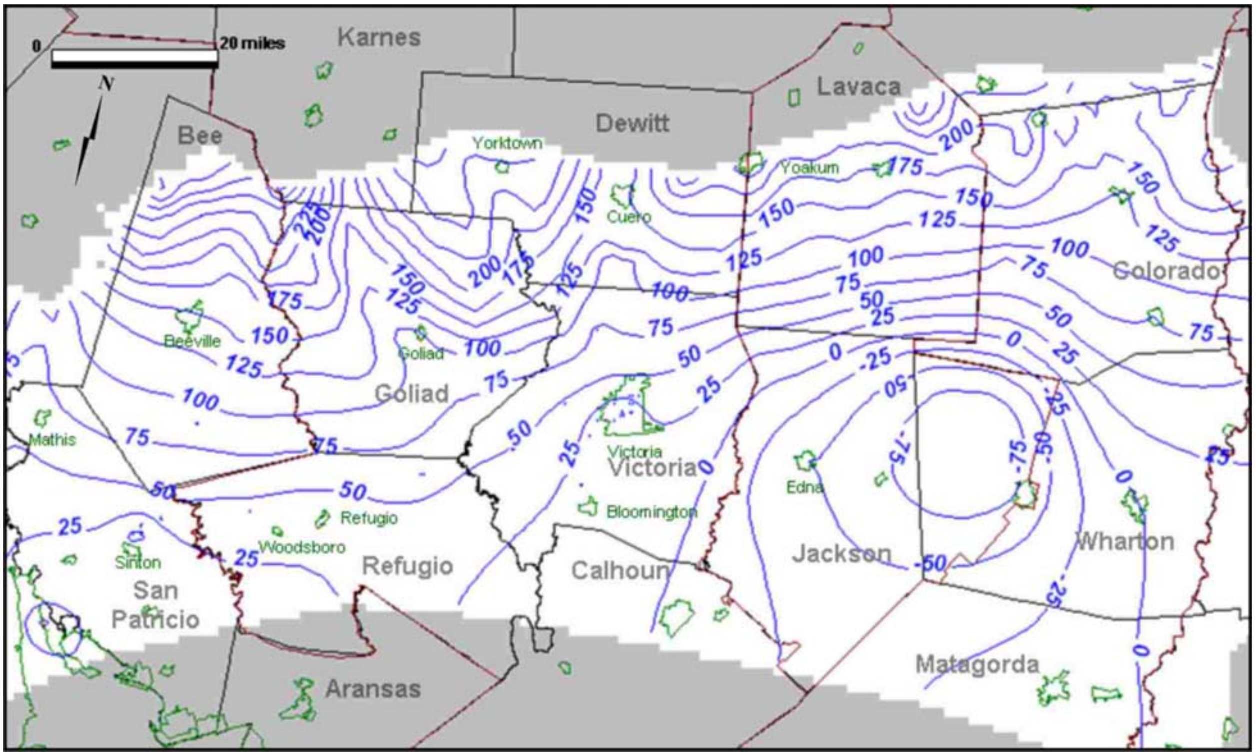


Figure 4C.19-20. Year 2060 Evangeline Groundwater Elevation: Local Supply Pumpage

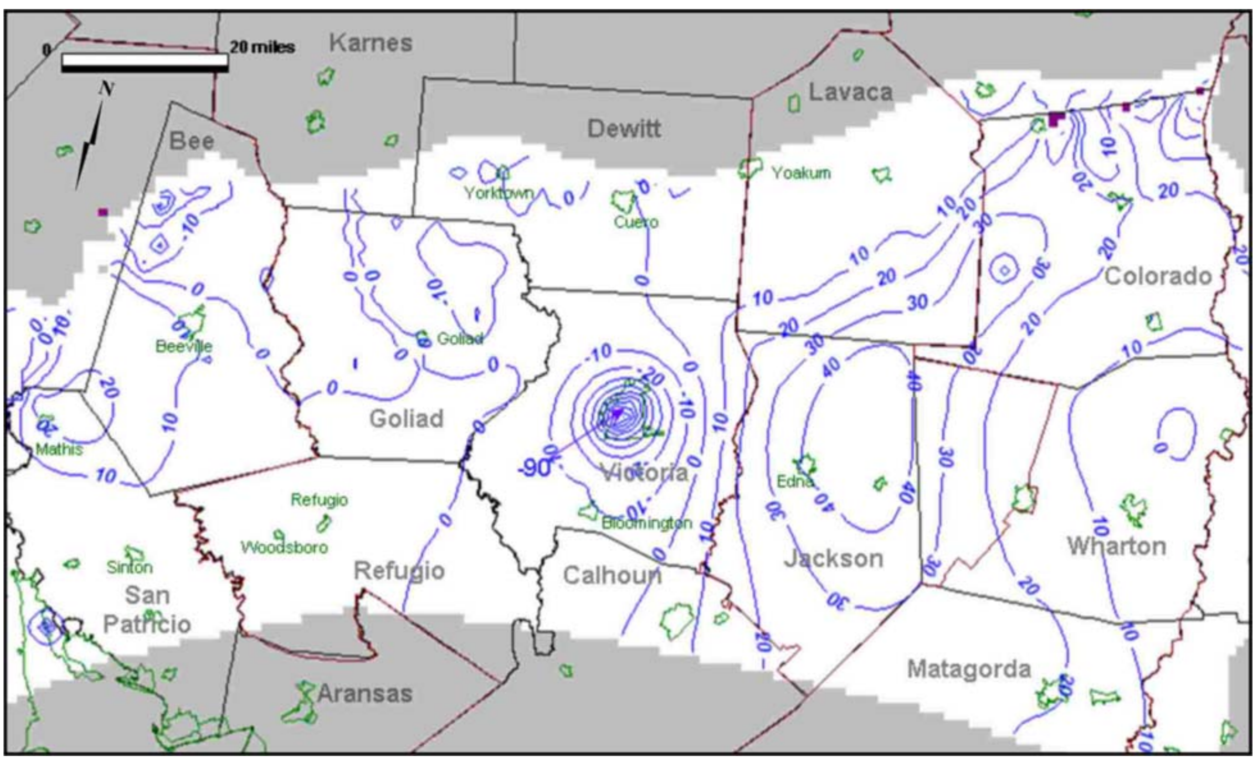


Figure 4C.19-21. 2000-2060 Evangeline Drawdown: Local Supply Pumpage

include the Lower Guadalupe Water Supply Project (LGWSP), the San Patricio Municipal Water District well field, and the City of Corpus Christi well field. The project locations are shown on Figure 4C.19-22. As previously discussed, it was determined during the technical evaluation that since these project wells are planned to fully penetrate the Evangeline Aquifer, these well fields were modeled using the Fully-Penetrating Model; local groundwater pumping demand was not included in this simulation. The following are brief descriptions of the proposed simulated projects.

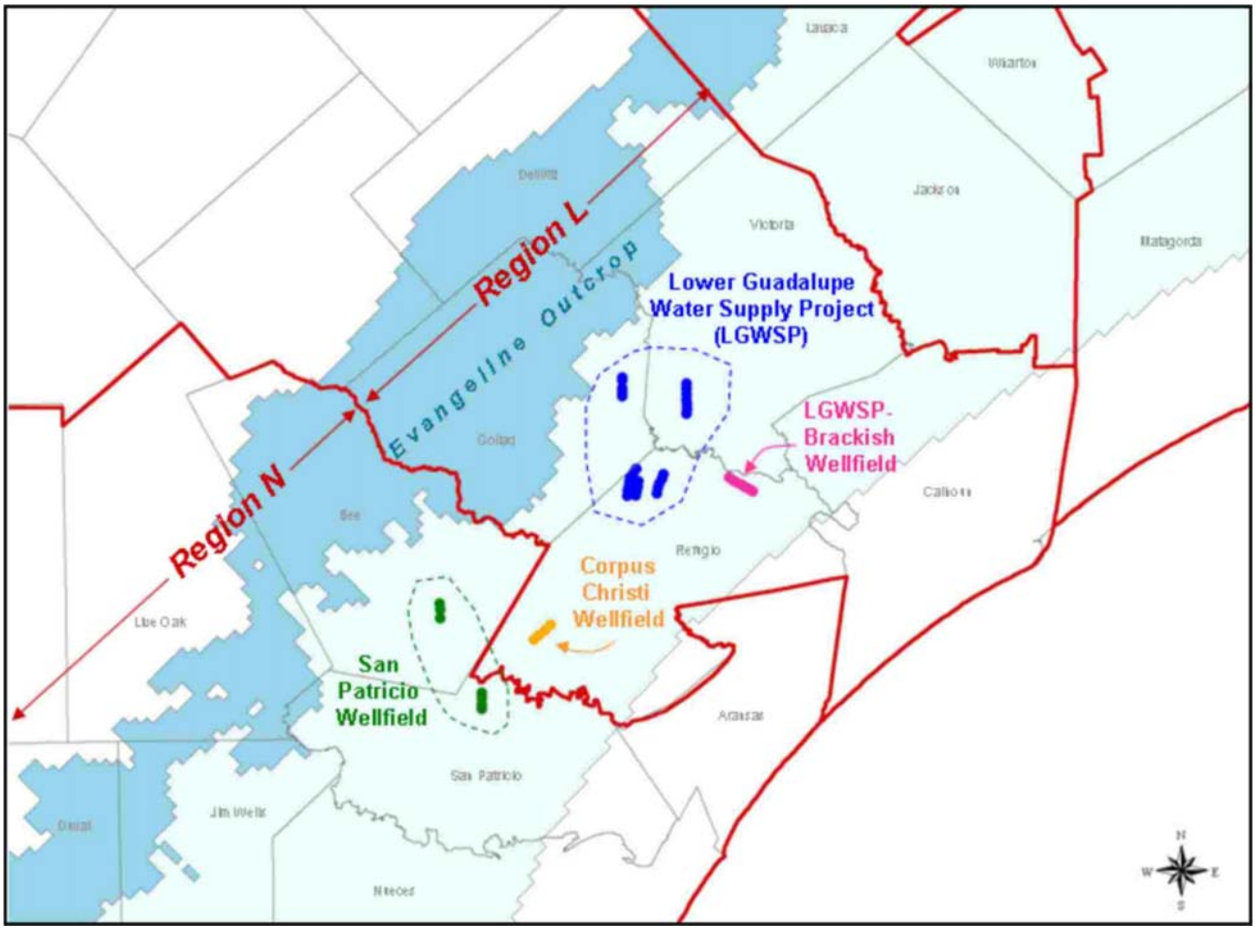


Figure 4C.19-22. Project Locations in the Evangeline Aquifer

<u>Lower Guadalupe Water Supply Project (LGWSP) Pumping</u>

The LGWSP includes three well fields in the Region L counties of Victoria, Goliad, and Refugio. This project is envisioned as a conjunctive use project in which surface water flows from the Guadalupe River would be used when available, and groundwater would be used to supplement this source, which is reduced in times of drought due to water rights restrictions. The projected groundwater use is dependent upon surface water availability calculated using the Guadalupe – San Antonio River Basin Water Availability Model (GSA WAM). Groundwater would be pumped at a variable annual rate starting in 2015 depending on modeled surface water availability for each year. Water would be cumulatively pumped from the three well fields at an average rate of 15,529 acft/yr, with a maximum pumping rate of 41,400 acft/yr during the drought of record. The LGWSP pumping per year, per county well field is shown on Table 4C.19-2. In Refugio County, 61 percent of the total LGWSP pumping was proportioned to sixteen 1,000-gpm wells spaced approximately 3,000-feet apart. In Victoria County, 24 percent of the total LGWSP pumping was proportioned to seven 1,000-gpm wells spaced at approximately 3,000 feet. In Goliad County, the remaining 15 percent of the total LGWSP pumping was proportioned to five 800-gpm wells spaced approximately 2,500 feet apart.

The brackish well field in Refugio County was also modeled using the Fully-Penetrating Model. The average pumping rate in this well field is 5,191 acft/yr and the maximum pumping rate is 13,840 acft/yr during the drought of record. The pumping was proportioned to seven, 1,000 gpm wells spaced approximately 3,000-feet apart.

Region N Project Pumping

Region N projects in neighboring counties were also modeled using the Fully-Penetrating Model. The San Patricio well field project includes two well fields in Bee and San Patricio Counties, each producing 5,500 acft/yr for a total of 11,000 acft/yr at a constant annual rate starting in 2010. The Bee County well field has three 1,100-gpm wells and the San Patricio County well field has four 850-gpm wells.

The City of Corpus Christi well field is located in Refugio County. Pumping comes online at 500 acft/yr in 2056, and increases to 7,000 acft/yr in 2060. This well field includes four 1,000-gpm wells.

All Region L and Region N project pumping, modeled using the Fully-Penetrating Model is shown in Figure 4C.19-23.

Table 4C.19-2.
Lower Guadalupe Water Supply Project
Pumping Per County Well Field (acft)
(2000 to 2060)

Year	Goliad	Refugio	Victoria	Total	Refugio (Brackish Well Field)	Total (Including Brackish Well Field)
2000	0	0	0	0	0	0
2001	0	0	0	0	0	0
2002	0	0	0	0	0	0
2003	0	0	0	0	0	0
2004	0	0	0	0	0	0
2005	0	0	0	0	0	0
2006	0	0	0	0	0	0
2007	0	0	0	0	0	0
2008	0	0	0	0	0	0
2009	0	0	0	0	0	0
2010	0	0	0	0	0	0
2011	0	0	0	0	0	0
2012	0	0	0	0	0	0
2013	0	0	0	0	0	0
2014	0	0	0	0	0	0
2015	1,964	7,986	3,142	13,092	4,377	17,469
2016	4,926	20,034	7,882	32,842	10,979	43,821
2017	4,623	18,801	7,397	30,822	10,304	41,126
2018	3,136	12,753	5,018	20,907	6,989	27,896
2019	3,315	13,482	5,304	22,102	7,389	29,491
2020	5,852	23,798	9,363	39,012	13,042	52,054
2021	6,210	25,254	9,936	41,400	13,840	55,240
2022	6,210	25,254	9,936	41,400	13,840	55,240
2023	3,105	12,627	4,968	20,700	6,920	27,620
2024	518	2,105	828	3,450	1,153	4,603
2025	908	3,692	1,453	6,053	2,024	8,077
2026	313	1,272	501	2,086	697	2,783
2027	391	1,592	626	2,610	872	3,482
2028	4,308	17,520	6,893	28,721	9,601	38,322
2029	5,882	23,922	9,412	39,217	13,110	52,327
2030	4,663	18,963	7,461	31,087	10,393	41,480

Page 1 of 2

Table 4B.19-2 Continued

Year	*Goliad*	*Refugio*	*Victoria*	*Total*	*Refugio (Brackish Well Field)*	*Total (Including Brackish Well Field)*
2031	1,553	6,314	2,484	10,350	3,460	13,810
2032	1,545	6,283	2,472	10,300	3,443	13,743
2033	4,102	16,680	6,563	27,344	9,141	36,485
2034	0	0	0	0	0	0
2035	1,553	6,314	2,484	10,350	3,460	13,810
2036	2,036	8,279	3,257	13,573	4,537	18,110
2037	3,623	14,732	5,796	24,150	8,073	32,223
2038	1,163	4,731	1,861	7,756	2,593	10,349
2039	0	0	0	0	0	0
2040	576	2,343	922	3,840	1,284	5,124
2041	0	0	0	0	0	0
2042	1,342	5,457	2,147	8,945	2,990	11,936
2043	115	468	184	767	256	1,023
2044	1,035	4,209	1,656	6,900	2,307	9,207
2045	651	2,649	1,042	4,343	1,452	5,795
2046	2,570	10,450	4,112	17,131	5,727	22,859
2047	40	164	65	269	90	359
2048	2,411	9,806	3,858	16,076	5,374	21,450
2049	2,146	8,728	3,434	14,309	4,784	19,092
2050	5,380	21,879	8,608	35,868	11,991	47,859
2051	1,035	4,209	1,656	6,900	2,307	9,207
2052	1,296	5,269	2,073	8,638	2,888	11,526
2053	0	0	0	0	0	0
2054	3,797	15,442	6,075	25,314	8,463	33,777
2055	5,274	21,448	8,439	35,161	11,755	46,916
2056	2,379	9,676	3,807	15,862	5,303	21,165
2057	321	1,307	514	2,142	716	2,858
2058	0	0	0	0	0	0
2059	2,294	9,330	3,671	15,295	5,113	20,408
2060	2,588	10,523	4,140	17,250	5,767	23,017
2015-2060 Average:	**2,329**	**9,473**	**3,727**	**15,529**	**5,191**	**20,720**
Maximum:	**6,210**	**25,254**	**9,936**	**41,400**	**13,840**	**55,240**

Page 2 of 2

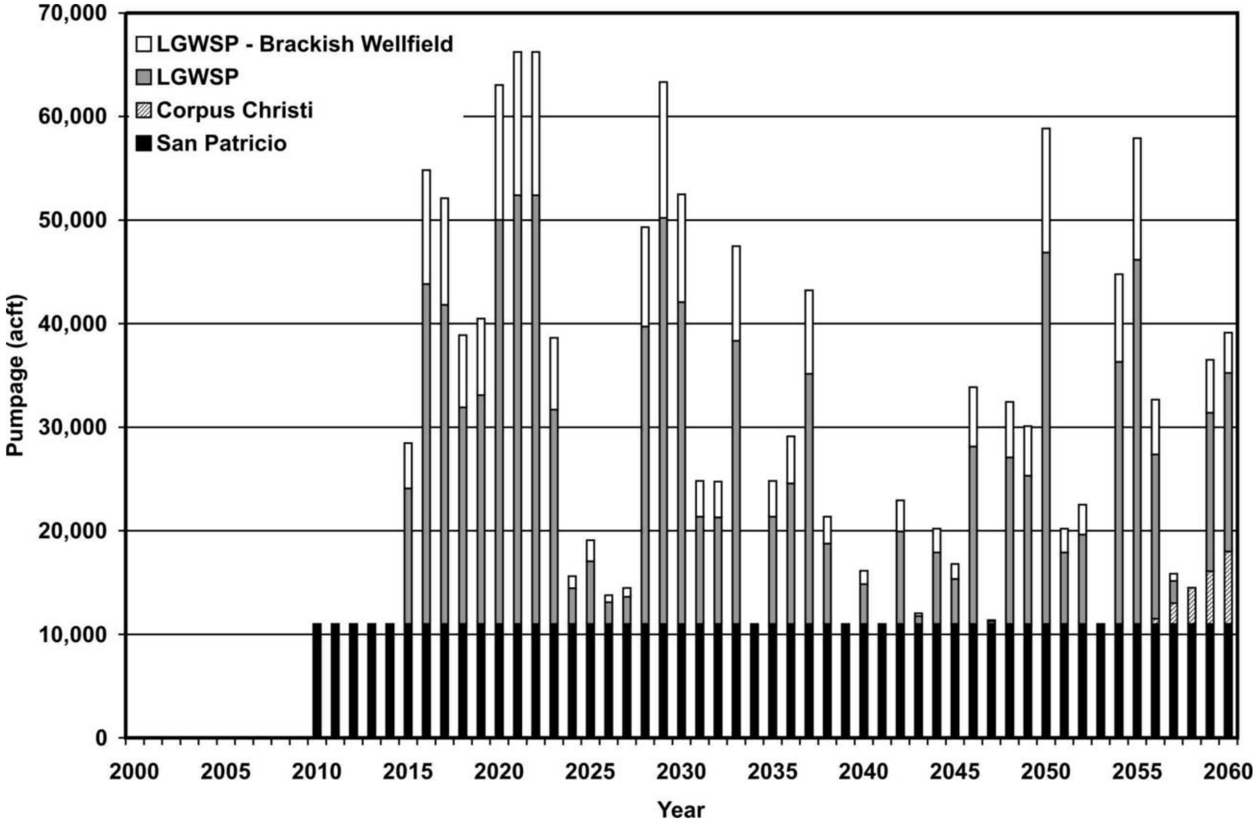


Figure 4C.19-23. Groundwater Project Predictive Pumping

4C.19.4.2 Groundwater Project Predictive Simulation

The Fully-Penetrating Model was used to evaluate drawdowns from fully-penetrating project wells in the Evangeline Aquifer. Local groundwater pumpage was not included in this model and therefore model results only show the effects of LGWSP, San Patricio, and Corpus Christi project pumping. This model is appropriate when determining relative changes in groundwater levels rather than absolute groundwater elevations.[3] Therefore, only drawdown figures from the Fully-Penetrating Model will be presented.

Predictive Evangeline Aquifer drawdowns during the 2022 model-simulated drought are shown in Figure 4C.19-24. The maximum drawdown attributed to LGWSP is 110 feet in the Refugio County well field. Impacts to the City of Victoria due to the modeled groundwater projects are less than 10 feet. Drawdown in the San Patricio project area is between 30 and 40 feet.

[3] Chowdhury, A., *GAM run 05-04*, Texas Water Development Board, January 23, 2005.

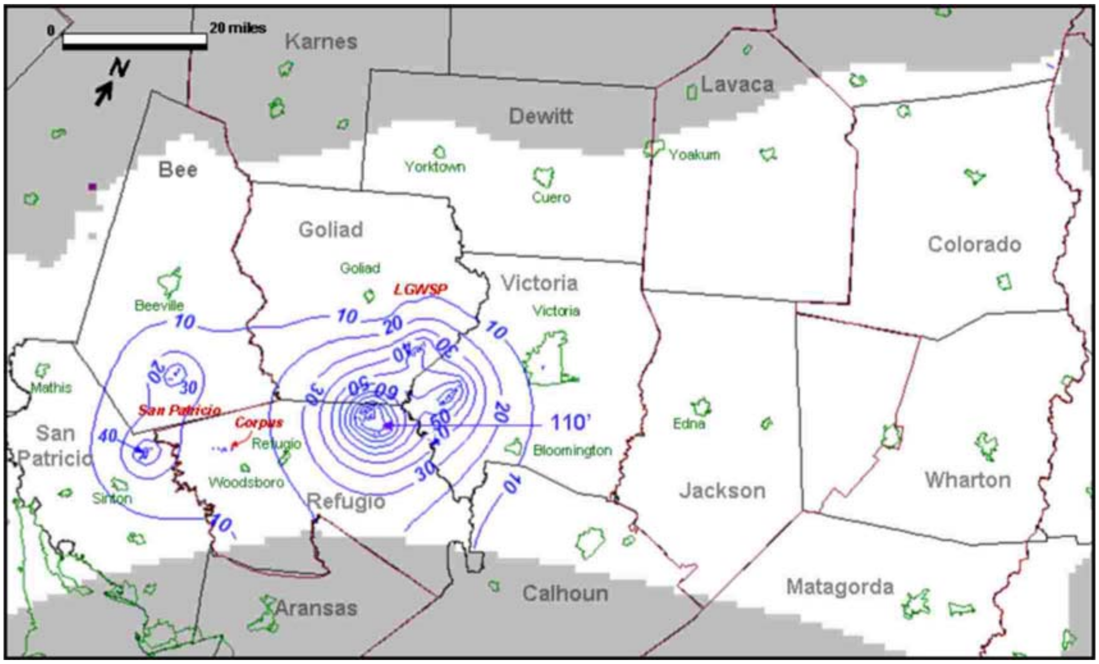


Figure 4C.19-24. Groundwater Project Predictive Simulation—2000 to 2022 Evangeline Drawdown (During Drought)

Predictive Evangeline Aquifer drawdowns in 2024, 2 years after the end of the model-simulated drought, are shown in Figure 4C.19-25. The water levels rebound significantly in Goliad, Refugio and Victoria Counties to approximately 20 feet of drawdown attributed to the LGWSP. The San Patricio project maintains approximately 30 to 40 feet of drawdown, since its pumpage rate remains constant.

The long term 2000 to 2060 drawdown in the Evangeline Aquifer is shown in Figure 4C.19-26. LGWSP pumping from the Evangeline Aquifer in 2060 was 17,250 acft, slightly above the LGWSP pumping average of 15,529 acft/yr. The drawdown attributed to the LGWSP is approximately 40 feet, the drawdown attributed to the San Patricio project is approximately 40 feet, and the drawdown attributed to the Corpus Christi project, which comes online in 2056, is approximately 40 feet.

Predictive Chicot Aquifer drawdowns during the 2022 model-simulated drought are shown in Figure 4C.19-27. The drawdown in Goliad and Victoria Counties attributed to the LGWSP is approximately 5 feet and the drawdown in Bee County attributed to the San Patricio project is also approximately 5 feet. There is a small area in Bee County in the Fully-Penetrating Model near the 10 foot contour on Figure 4C.19-27 where the model has minor, local anomaly of

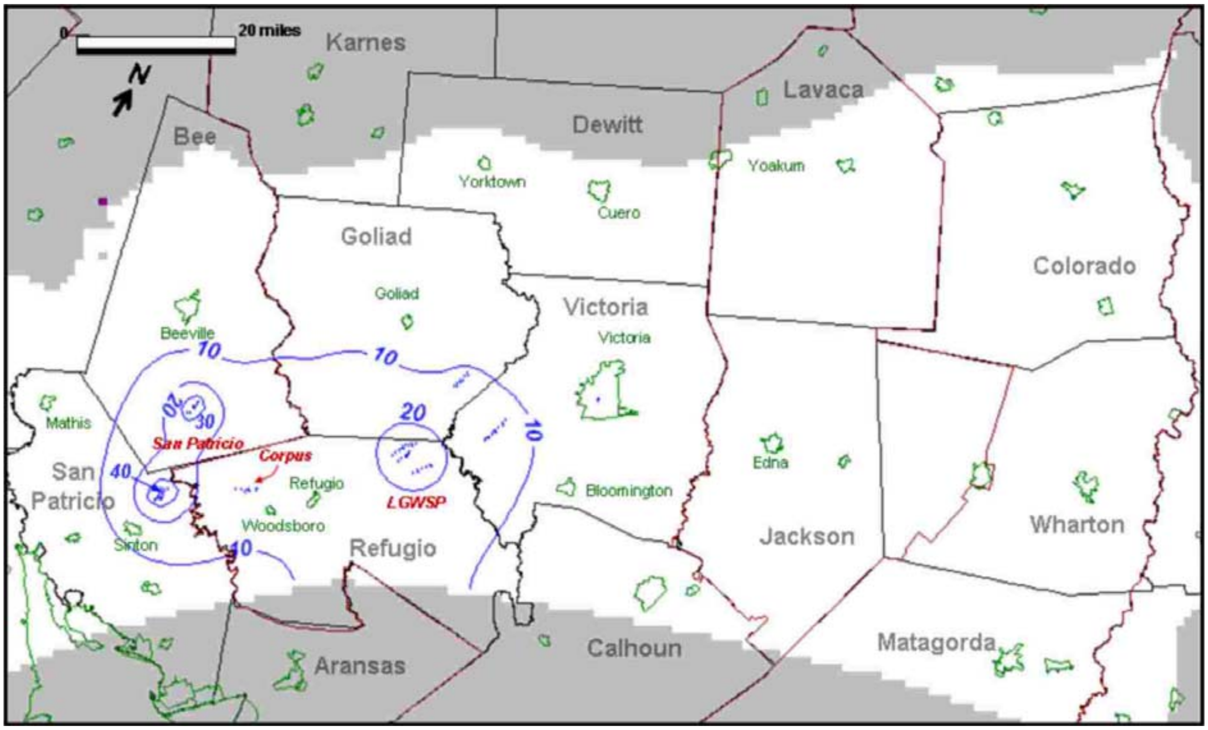


Figure 4C.19-25. Groundwater Project Predictive Simulation —2000 to 2024 Evangeline Drawdown (After Drought)

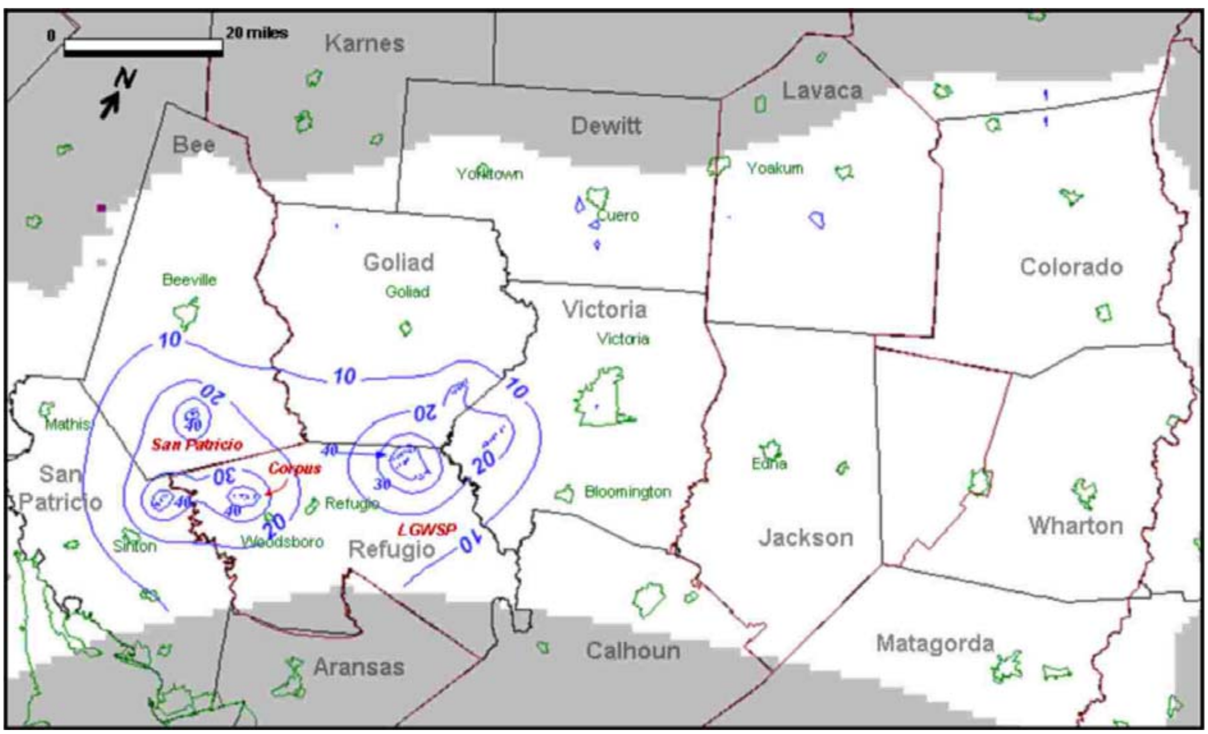


Figure 4C.19-26. Groundwater Project Predictive Simulation —2000-2060 Evangeline Drawdown

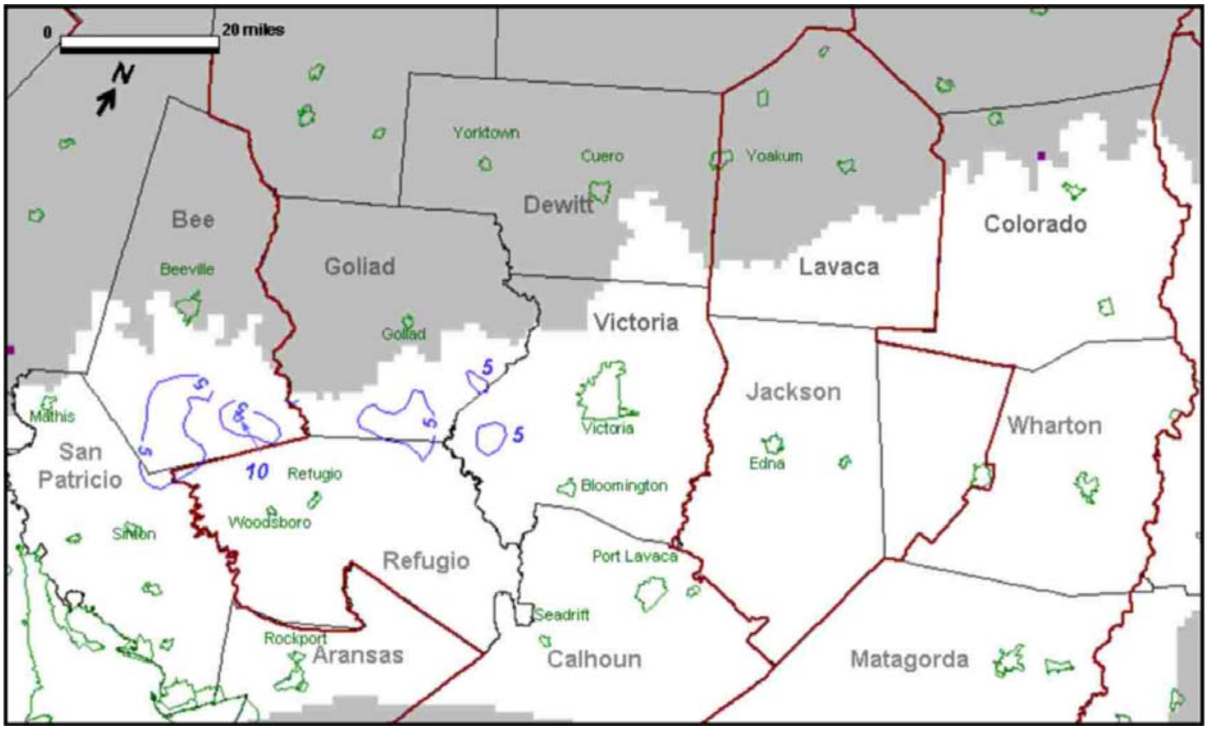


Figure 4C.19-27. Groundwater Project Predictive Simulation —2000 to 2022 Chicot Drawdown (During Drought)

which approximately 6 feet of drawdown can be attributed. This is known because even with zero pumping in the Fully-Penetrating Model, approximately 6 feet of drawdown is present in this area. This minor ‘extra’ drawdown will also be present in Figures 4C.19-28 and 4C.19-29.

Predictive Chicot Aquifer drawdown in 2024, 2 years after the model-simulated drought, is shown in Figure 4C.19-28. The drawdown in Goliad and Victoria Counties attributed to the LGWSP, although somewhat lessened, remains approximately 5 feet. The Bee County 5 feet cone of depression has slightly increased. This is a result of constant pumping in the San Patricio well field, whereas the LGWSP pumping fluctuates based on surface water availability.

The long-term 2000 to 2060 drawdown in the Chicot Aquifer is shown in Figure 4C.19-29. The drawdown attributed to the LGWSP is approximately 5 feet and the drawdown attributed to the San Patricio project is approximately 10 to 20 feet.

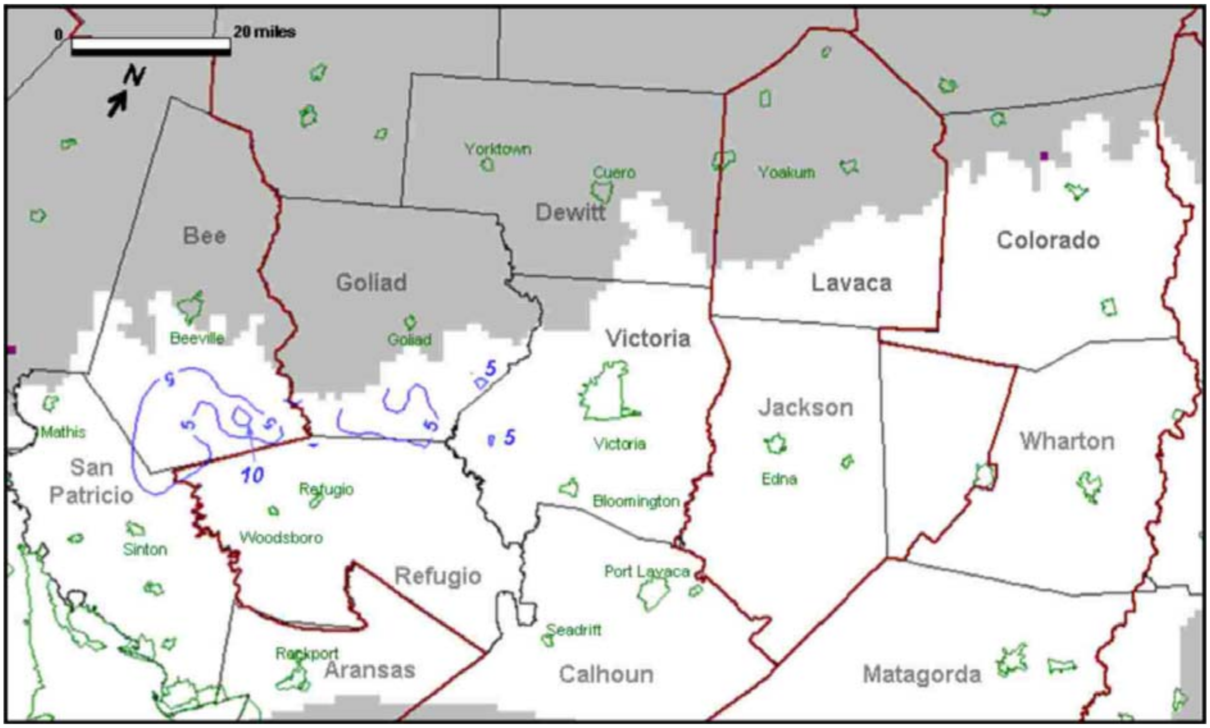


Figure 4C.19-28. Groundwater Project Predictive Simulation —2000 to 2024 Chicot Drawdown (After Drought)

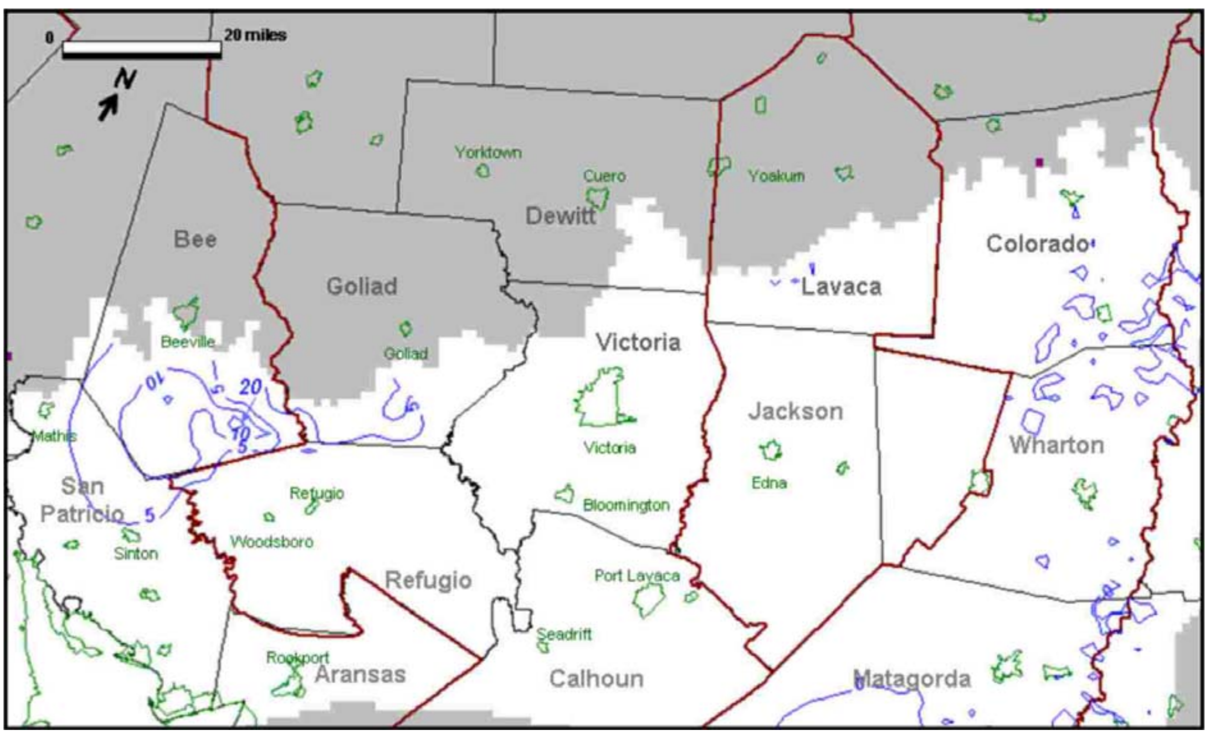


Figure 4C.19-29. Groundwater Project Predictive Simulation —2000 to 2060 Chicot Drawdown

4C.19.5 Total Central Gulf Coast Aquifer Drawdown

4C.19.5.1 Total Drawdown in the Evangeline Aquifer

In order to calculate total, cumulative drawdown effects of the aquifer system from both local supply pumpage and groundwater development projects, the drawdown from both simulations was added together. Figure 4C.19-30, Figure 4C.19-31, and Figure 4C.19-32 respectively illustrate the total drawdown in the Evangeline Aquifer with local supply pumpage, LGWSP pumpage, and Region N project pumpage at the end of the 6-year simulated drought (year 2022), 2 years after the drought in 2024, and the long-term drawdown in 2060.

Water levels near the City of Victoria during the 2022 drought have been drawn down 10 feet from 1999 conditions as shown in Figure 4C.19-30. (Recall that a cone of depression already existed in 1999 due to historical pumping). The total drawdown in the LGWSP Refugio County well field at the height of the simulated drought is approximately 110 feet, the total drawdown in the LGWSP Goliad County well field is approximately 50 feet, and the total drawdown in the LGWSP Victoria County well field is 70 feet. The total drawdown in the San Patricio well fields is approximately 40 feet.

Figure 4C.19-31 illustrates the recovery of the Evangeline Aquifer water levels 2 years after the end of the drought. Water levels near the City of Victoria rebound approximately 90 feet from 1999 conditions. The total drawdown in the LGWSP Refugio County well field is 20 feet, and the total drawdown in the San Patricio well field maintains approximately 40 feet of drawdown due to constant pumping in this well field.

Figure 4C.19-32 illustrates the long-term 2060 total drawdown. Water levels near the City of Victoria rebound approximately 90 feet from 1999 conditions and the total drawdown in the LGWSP Refugio County well field is approximately 40 feet. The total drawdown in the San Patricio well field in Bee and San Patricio Counties is 40 feet and 50 feet, respectively. The drawdown in the Corpus Christi well field, which comes online in 2056, is approximately 50 feet.

Figure 4C.19-33, Figure 4C.19-34, and Figure 4C.19-35 are similar to the previous set of figures; however, the LGWSP brackish well field was included in this model run. The brackish well field was modeled using the same surface water availability pumping signal as the LGWSP. The average pumping rate in this well field was 5,191 acft/yr and at a maximum of 13,840 acft/yr during the drought of record.

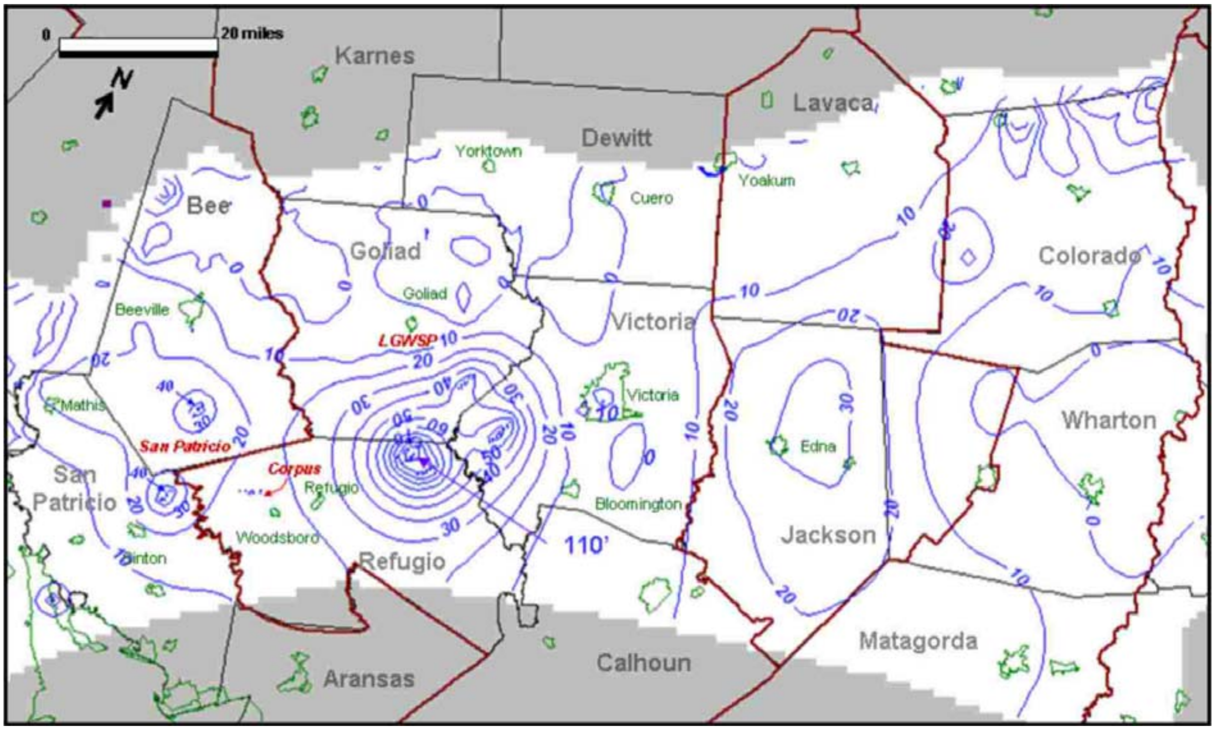


Figure 4C.19-30. Total Evangeline Drawdown <u>During</u> Drought—2000 to 2022

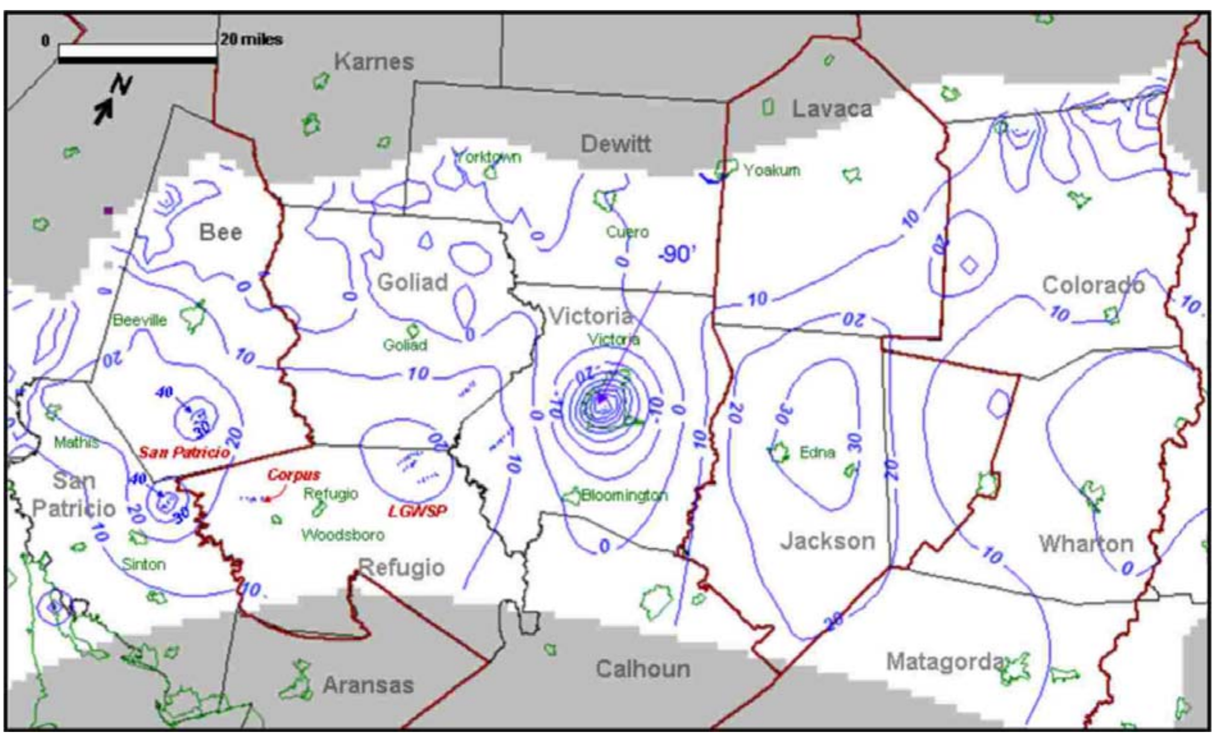


Figure 4C.19-31. Total Evangeline Drawdown <u>After</u> Drought—2000 to 2024

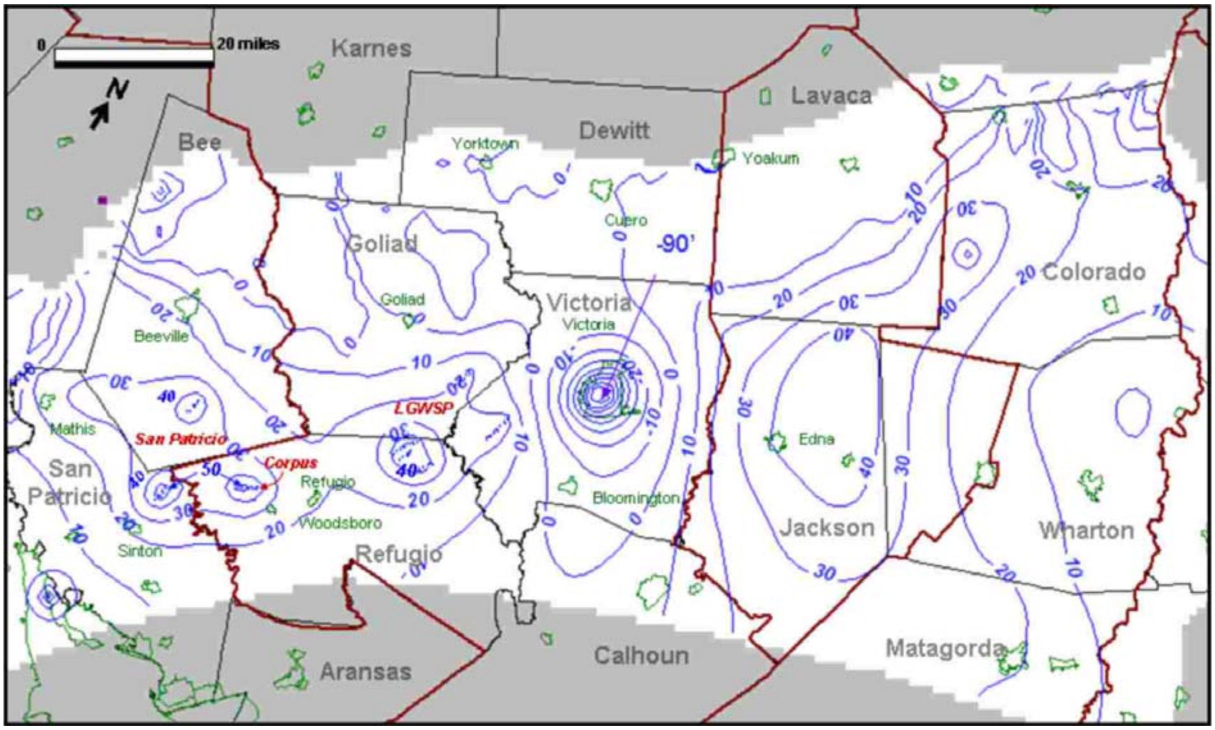


Figure 4C.19-32. Total Evangeline Drawdown—2000 to 2060

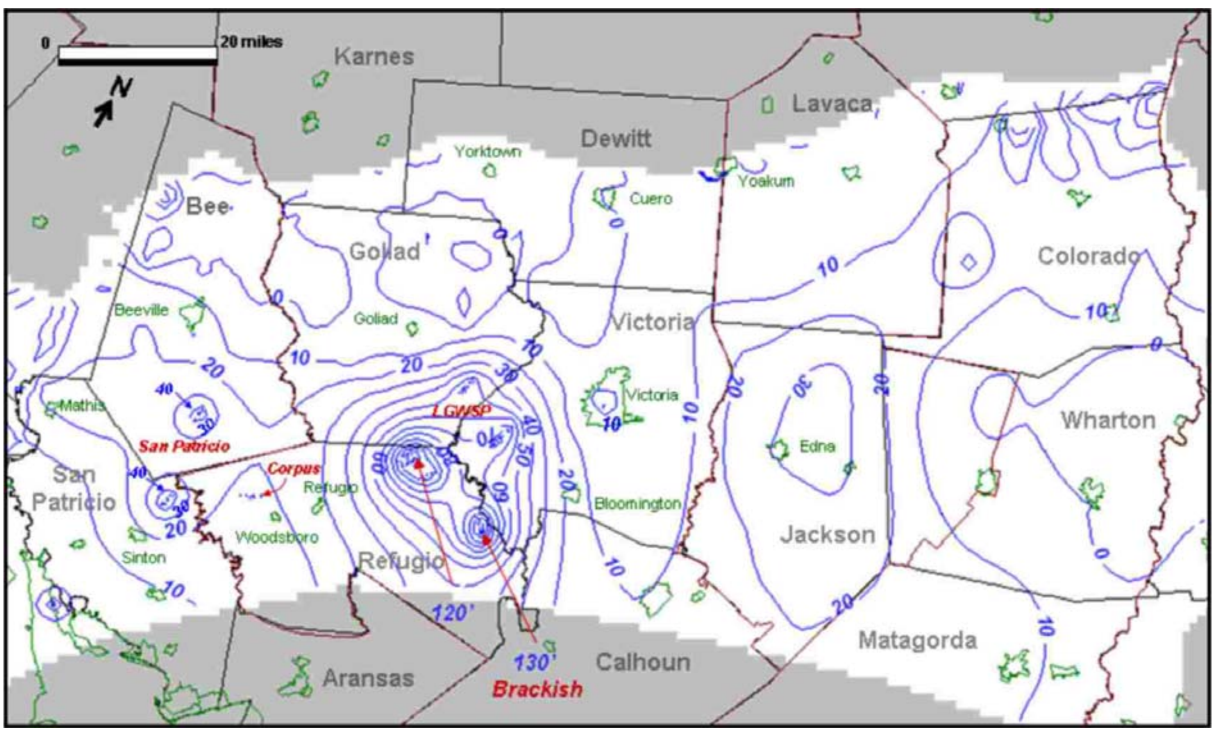


Figure 4C.19-33. Total Drawdown (with Brackish Well Field)—2000 to 2022
Evangeline Drawdown During Drought

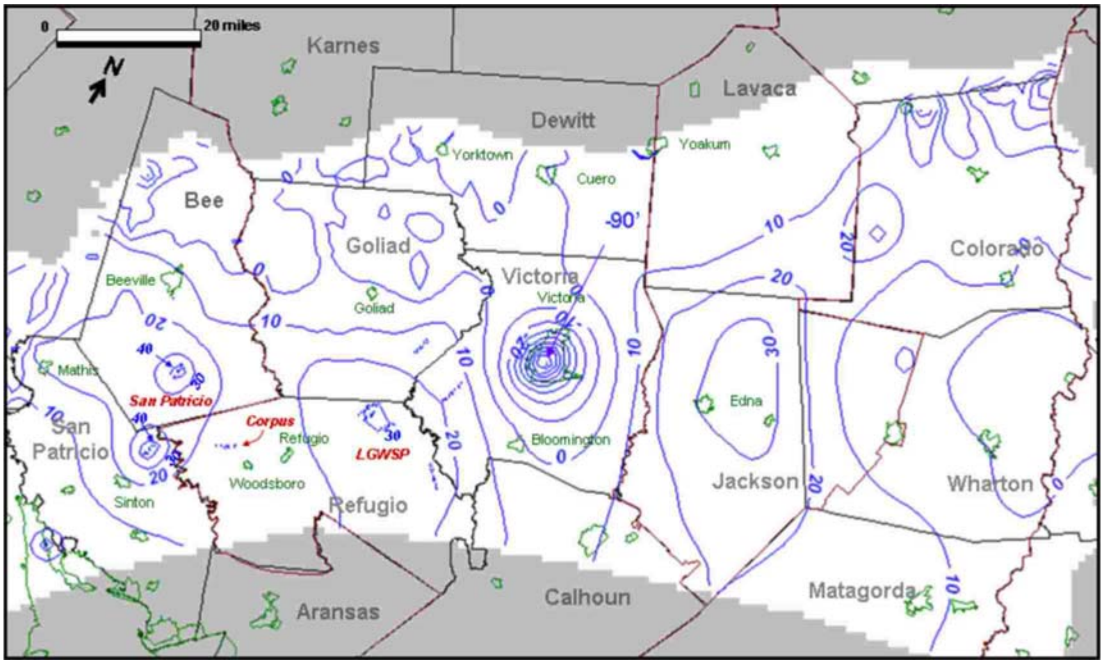


Figure 4C.19-34. Total Drawdown (with Brackish Well Field)—2000 to 2024 Evangeline Drawdown <u>After</u> Drought

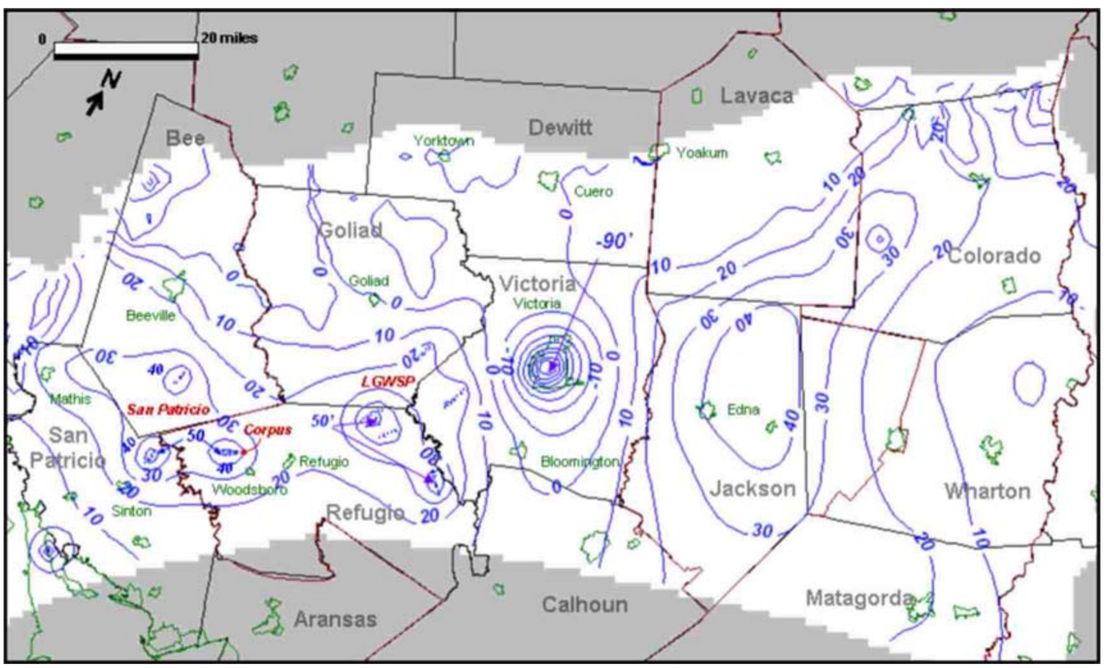


Figure 4C.19-35. Total Drawdown (with Brackish Well Field)—2000 to 2060 Evangeline Drawdown

Figure 4C.19-33 illustrates the total drawdown during the model-simulated drought. There is 130 feet of drawdown in the LGWSP brackish well field and 120 feet of drawdown in the LGWSP Refugio County well field. The brackish well field contributes an additional 10 feet of drawdown to the LGWSP area.

Figure 4C.19-34 illustrates the total drawdown 2-years after the model-simulated drought. There is 30 feet of drawdown near the LGWSP Refugio County well field and the 20 foot drawdown contour has expanded to include the brackish well field.

The long-term 2060 total drawdown shown in Figure 4C.19-35 shows approximately 50 feet of drawdown in the LGWSP well field in Refugio County and the LGWSP brackish well field.

Figure 4C.19-36 and Figure 4C.19-37 illustrate the Evangeline Aquifer drawdown in the project pumping centers and in the City of Victoria throughout the 60-year model run. The first line represents calculated drawdown from local groundwater pumping; the second line represents total drawdown from the local groundwater pumping, plus the LGWSP pumping, plus Region N projects; and the third line represents drawdown from the local groundwater pumping, plus the LGWSP pumping, Region N projects, plus the LGWSP brackish well field.

Graph 1 on Figure 4C.19-36 illustrates the rebounding effect of water levels near the City of Victoria. During the drought conditions of 2020 to 2022, water levels in the Evangeline Aquifer declined approximately 10 feet from 1999 water levels. However, water level declines near the City of Victoria may be large as 110 feet during drought conditions. For example, in 2010 the groundwater recovery is 100 feet and in 2022 the drawdown is 10 feet, totaling 110 feet of drawdown. However, after drought cycles, the aquifer quickly recovers to pre-drought conditions. Graph 1 also illustrates that a minimal amount of drawdown near the City of Victoria is attributed to the LGWSP. Approximately 6 feet of drawdown is attributed to the LGWSP and approximately 8 feet drawdown is attributed to the LGWSP plus brackish well field during drought conditions.

Graph 2 on Figure 4C.19-36 is in the LGWSP Goliad well field, which comes online in 2015. During drought conditions, the LGWSP causes the Evangeline Aquifer water level to decline approximately 53 feet from the local groundwater level. During non-drought conditions, (e.g., 2060), the LGWSP contributes approximately 22 feet of additional drawdown from the local groundwater level.

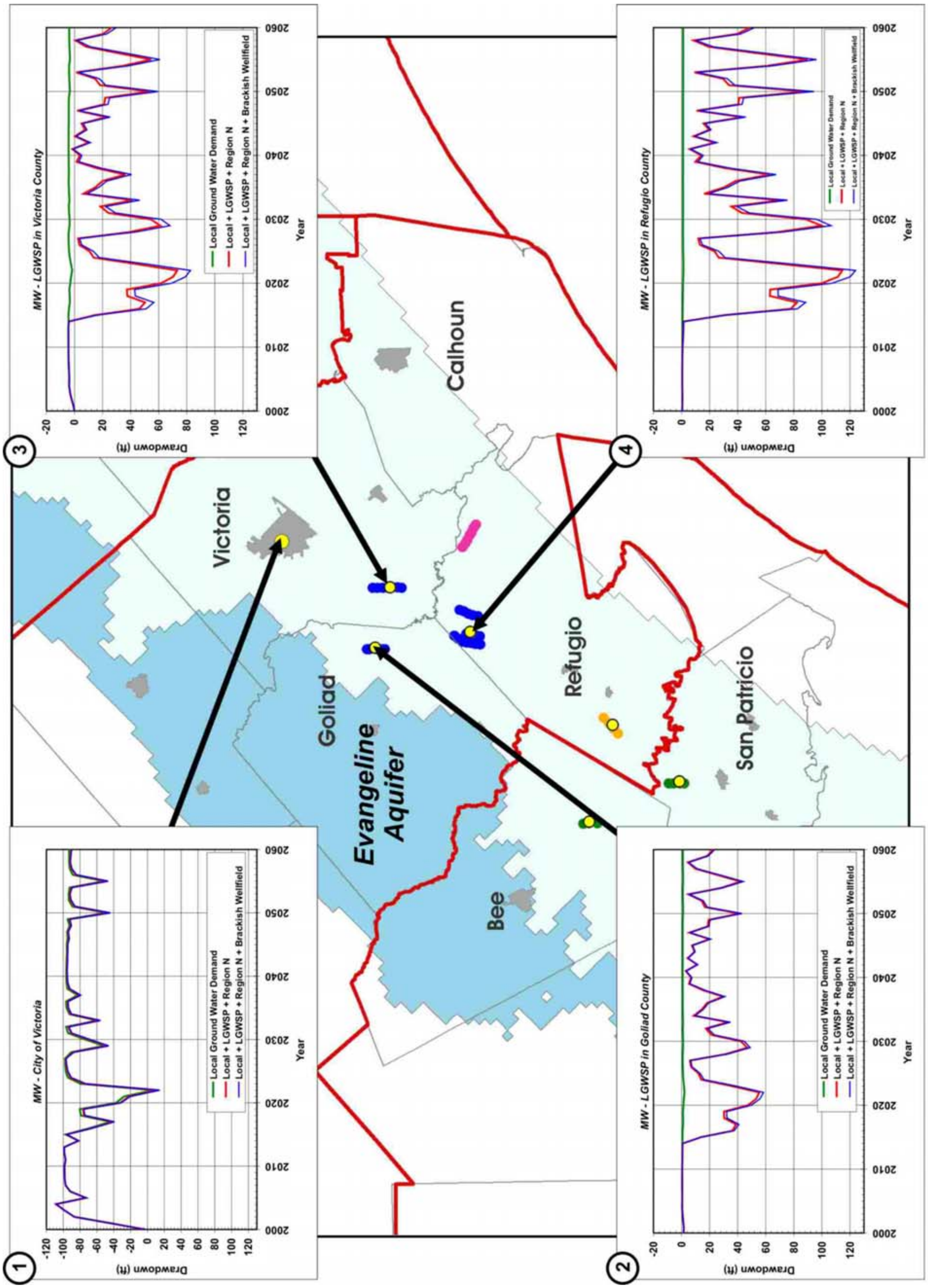


Figure 4C.19-36. Predictive Drawdown Hydrographs for the Evangeline Aquifer near Pumping Centers

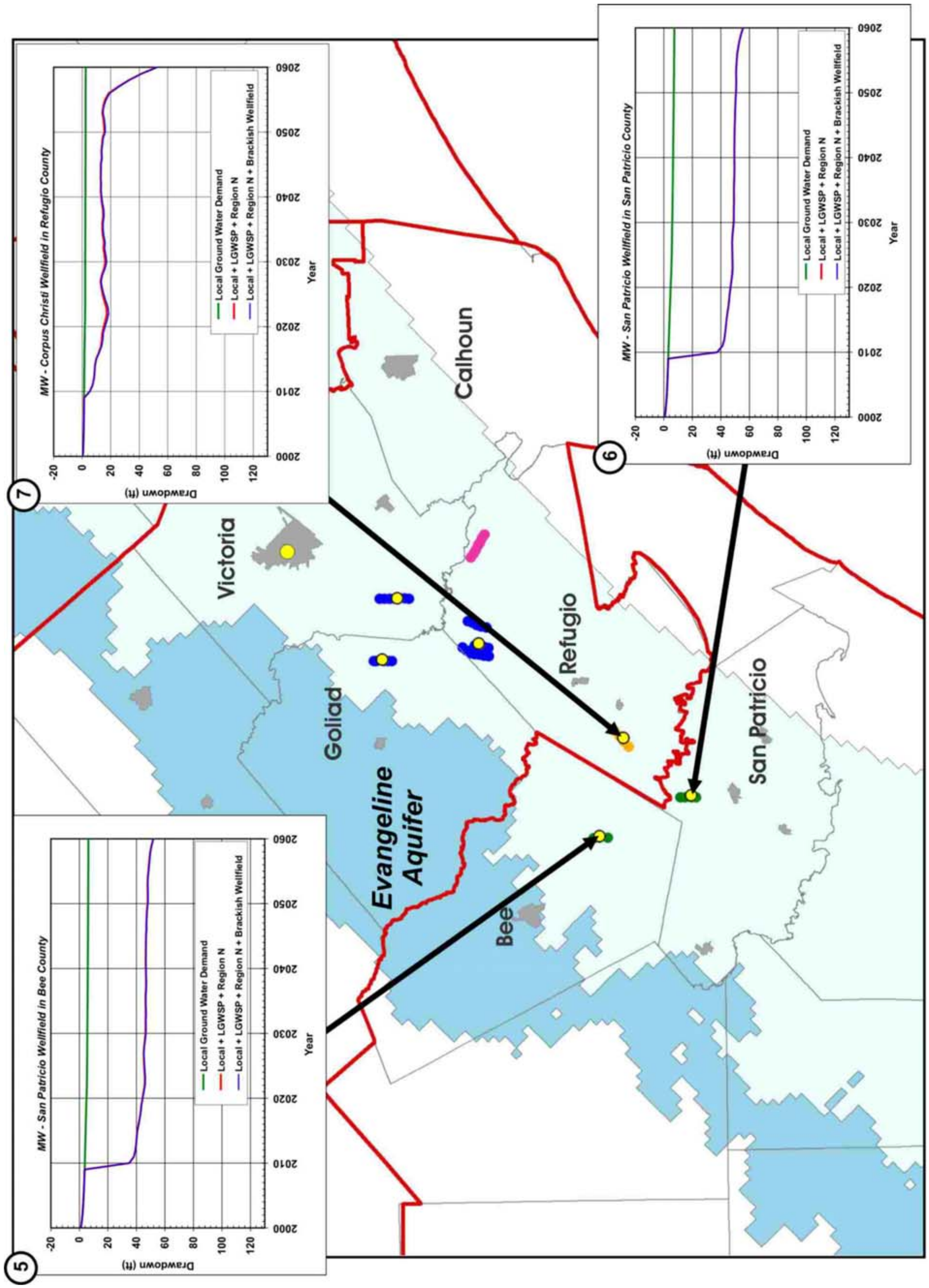


Figure 4C.19-37. Predictive Drawdown Hydrographs for the Evangeline Aquifer near Pumping Centers

Graph 3 on Figure 4C.19-36 is in the LGWSP Victoria well field, which comes online in 2015. During drought conditions, the LGWSP causes the Evangeline Aquifer water level to decline approximately 75 feet from the local groundwater level. The LGWSP plus brackish well field causes the Evangeline Aquifer water level to decline approximately 84 feet from the local groundwater level during drought conditions. During non-drought conditions, (e.g., 2060), the LGWSP contributes approximately 30 feet of additional drawdown from the local groundwater levels.

Graph 4 on Figure 4C.19-36 is in the LGWSP Refugio well field, which also comes online in 2015. During drought conditions, the LGWSP causes the Evangeline Aquifer water level to decline approximately 113 feet from the local groundwater level and the LGWSP plus brackish well field causes the Evangeline Aquifer water level to decline approximately 123 feet from the local groundwater level. During non-drought conditions, (e.g., 2060), the LGWSP contributes approximately 47 feet of additional drawdown to the local groundwater levels.

The drawdown effects in the Evangeline Aquifer in the Region N well fields in Bee, San Patricio, and Refugio Counties are shown on graphs 5, 6, and 7 on Figure 4C.19-37. These well fields were modeled with constant pumping, as reflected by the constant drawdown starting in 2010 on all graphs. Graphs 5 and 6 are near the Region N's San Patricio well fields in Bee and San Patricio Counties. Evangeline Aquifer drawdown from local groundwater levels attributed to the San Patricio project in these counties is approximately 45 feet and 48 feet, respectively in 2060.

Graph 7 is in the Corpus Christi well field. This well field comes online in 2056. Drawdown in 2010 to 2055 reflects effects from the San Patricio well field and the LGWSP well field. The 2060 drawdown from local Evangeline Aquifer groundwater levels due all projects is approximately 50 feet in this well field.

Figure 4C.19-38 illustrates model-wide drawdown in the Evangeline Aquifer throughout the 60-year model run. This figure shows the total drawdown effects from the local groundwater pumping demand and the effects the local demand with Region L and Region N projects. The graphs illustrate that project pumping affects the aquifer significantly during drought near the pumping centers and less so away from the pumping centers. Figure 4C.19-38 also illustrates the rapid recovery of water levels when pumping is reduced in non-drought conditions.

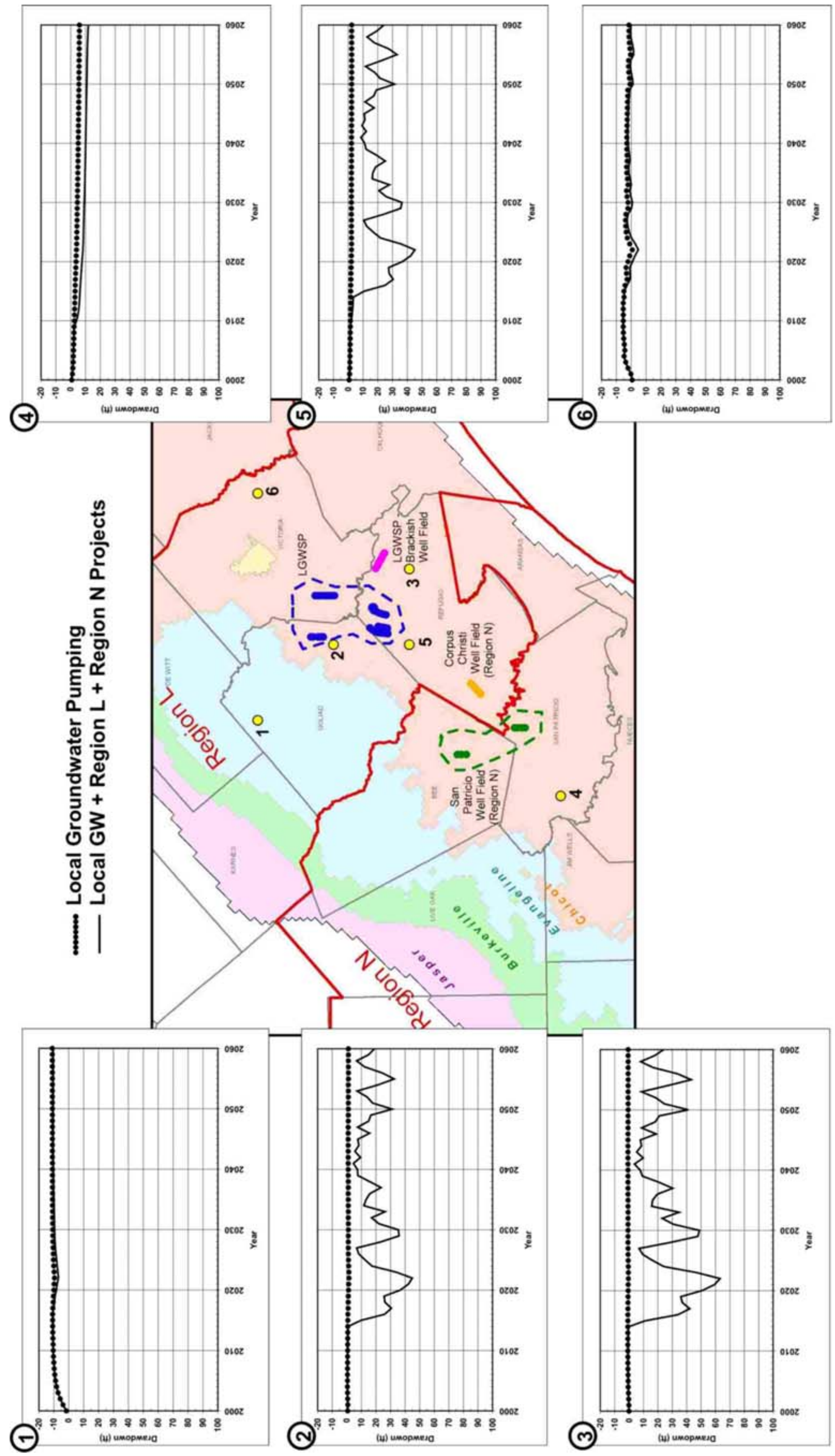


Figure 4C.19-38. Model-Wide Predictive Drawdown Hydrographs in the Evangeline Aquifer

4C.19.5.2 Total Drawdown in the Chicot Aquifer

In order to calculate cumulative drawdown effects of the aquifer system from both local supply pumpage and proposed groundwater project pumpage, the drawdown from both simulations was added together. Figure 4C.19-39, Figure 4C.19-40, and Figure 4C.19-41 respectively illustrate the total drawdown in the Chicot Aquifer with local supply pumpage, LGWSP pumpage, and Region N project pumpage at the end of the 6-year simulated drought (year 2022), 2 years after the drought in 2024, and the long-term drawdown in 2060.

As seen in the in Figure 4C.19-19, the water levels near the City of Victoria have rebounded approximately 30 feet from 1999 conditions because the pumping dataset used in the Partially-Penetrating Model reflects the city's reduced groundwater use. Also, as stated previously, portions of Goliad and Bee Counties display drawdowns of about 10 feet and 30 feet, respectively, that is not associated with any pumping activity. These localized phenomena appear to be artifacts of non-equilibrium conditions in the initial heads that were obtained from the historical transient simulations, and are not associated with any pumping.

Figure 4C.19-42 and Figure 4C.19-43 illustrate the Chicot Aquifer drawdown in the project pumping centers and in the City of Victoria throughout the 60-year model run. The first line represents calculated drawdown from local groundwater pumping; the second line represents total drawdown from the local groundwater pumping, plus the LGWSP pumping, plus Region N projects; and the third line represents drawdown from the local groundwater pumping, plus the LGWSP pumping, Region N projects, plus the LGWSP brackish well field.

Graph 1 on Figure 4C.19-42 illustrates the rebounding effect of water levels near the City of Victoria. During drought conditions of 2020 to 2022, water levels in the Chicot Aquifer decline approximately 4 feet due to local groundwater demand. The Region N and Region L projects have little effect on Chicot Aquifer water levels near the City of Victoria.

Graph 2 on Figure 4C.19-42 is in the LGWSP Goliad well field, which comes online in 2015. During drought conditions, the LGWSP causes Chicot Aquifer water levels to decline an additional 5 feet from the local groundwater level. During non-drought conditions (e.g., 2060), the LGWSP contributes approximately 2 feet of additional drawdown from the local groundwater levels.

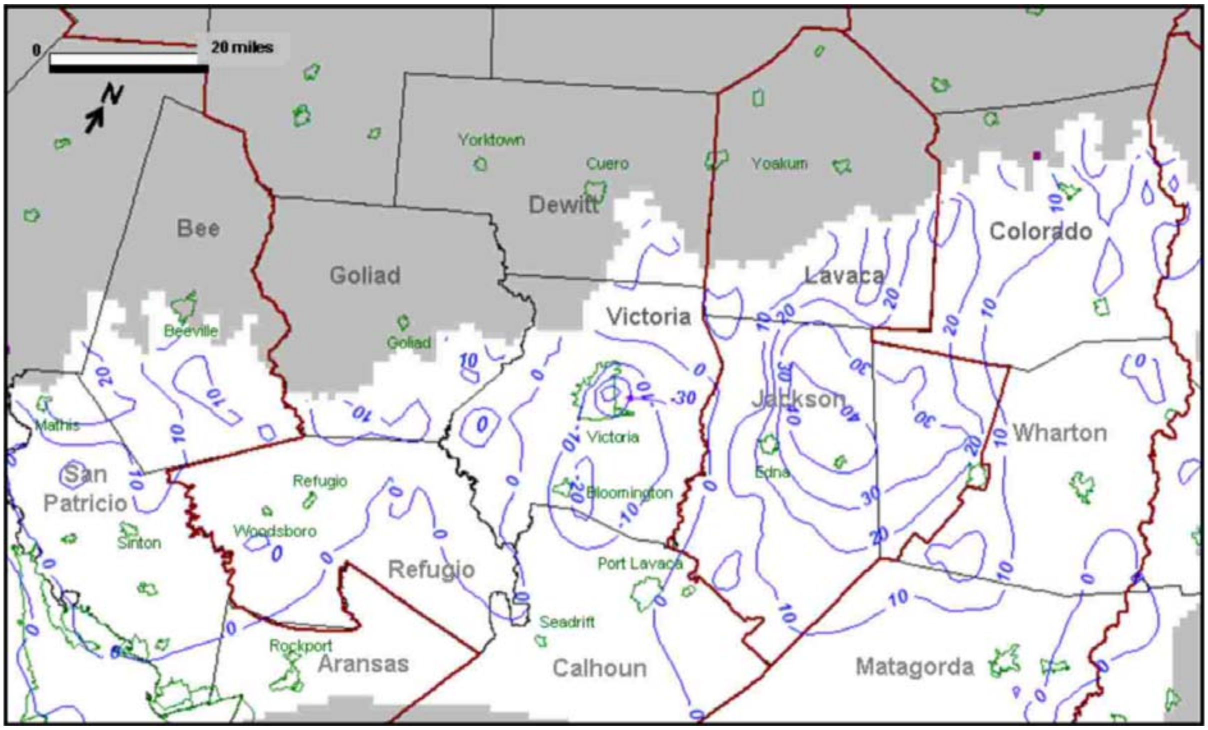


Figure 4C.19-39. Total Chicot Drawdown <u>During</u> Drought—2000 to 2022

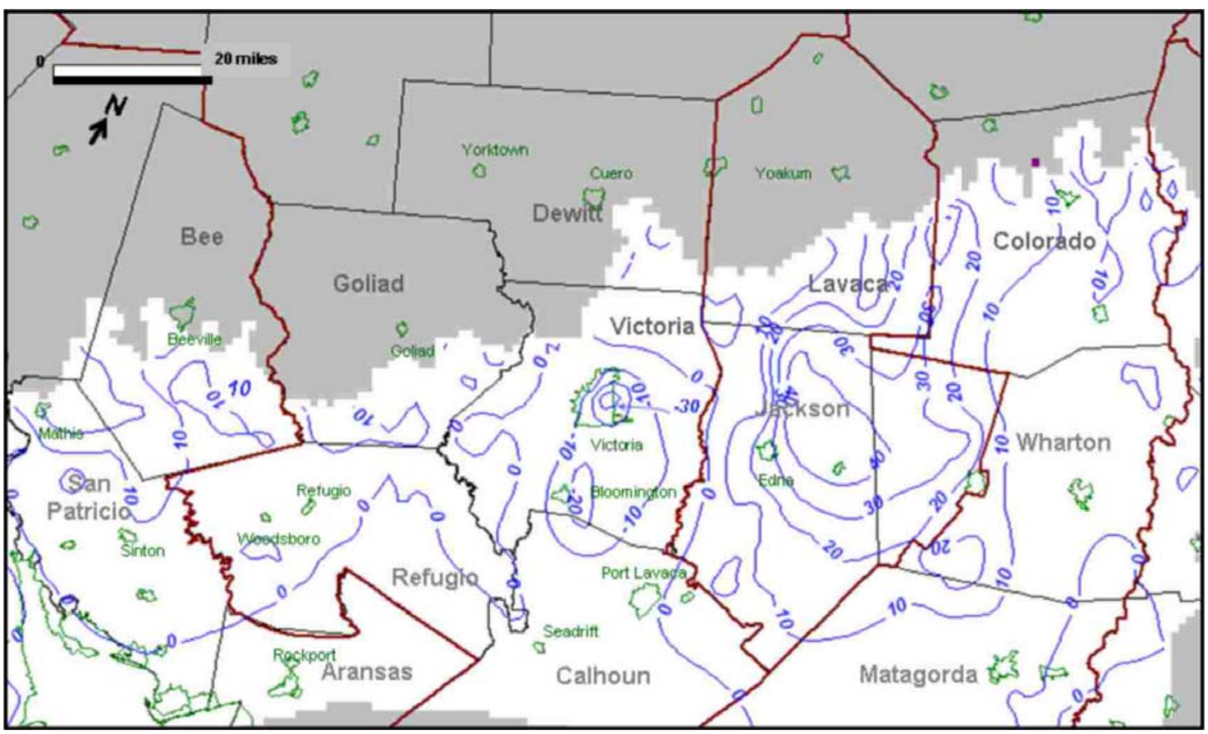


Figure 4C.19-40. Total Chicot Drawdown <u>After</u> Drought—2000 to 2024

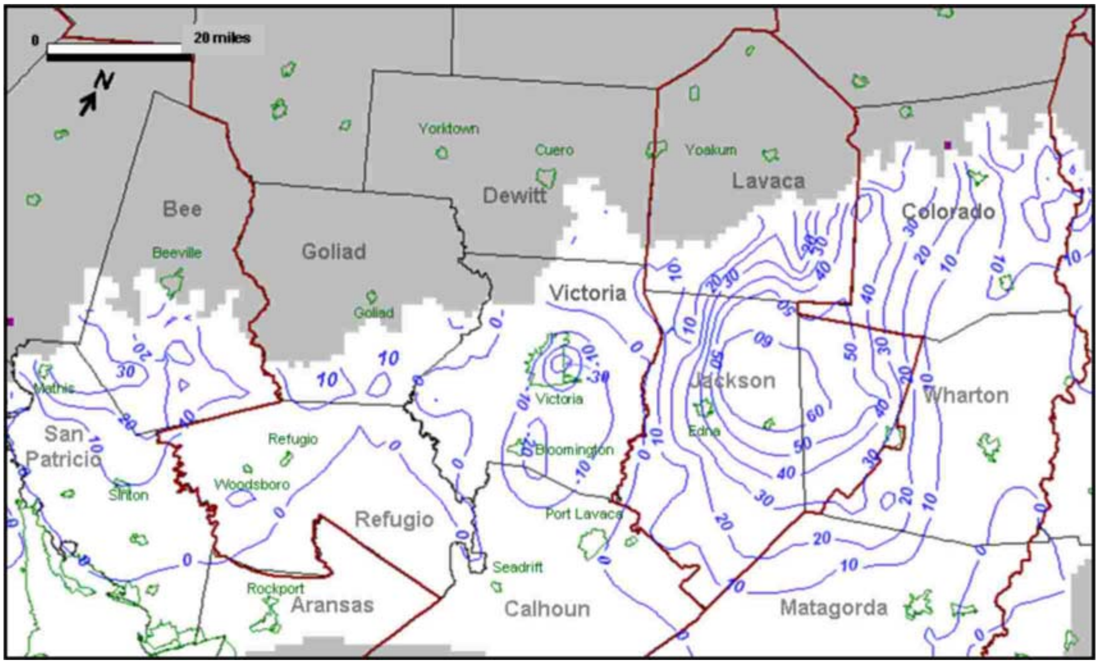


Figure 4C.19-41. Total Chicot Drawdown—2000 to 2060

Graph 3 on Figure 4C.19-42 is in the LGWSP Victoria well field, which also comes online in 2015. During drought conditions, the LGWSP causes the Chicot Aquifer water level to decline an additional 6 to 7 feet from the local groundwater level. During non-drought conditions, e.g. 2060, the LGWSP contributes approximately 3 feet of additional drawdown from the local groundwater levels.

Graph 4 on Figure 4C.19-42 is in the LGWSP Refugio well field, which also comes online in 2015. During drought conditions, the LGWSP causes the Chicot Aquifer water level to decline approximately 3 feet from the local groundwater level. During non-drought conditions, e.g. 2060, the LGWSP contributes approximately 1 feet of additional drawdown to the local groundwater levels.

The drawdown effects in the Chicot Aquifer in the Region N well fields in Bee, San Patricio, and Refugio Counties are shown on graphs 5, 6, and 7 of Figure 4C.19-43. These well fields were modeled with constant pumping, as reflected by the constant drawdown starting in 2010 on all graphs. Graphs 5 and 6 are near the Region N's San Patricio well fields in Bee and San Patricio Counties. Chicot Aquifer drawdown from local groundwater levels attributed to the San Patricio project in Bee and San Patricio Counties is an additional 10 feet and 7 feet, respectively in 2060.

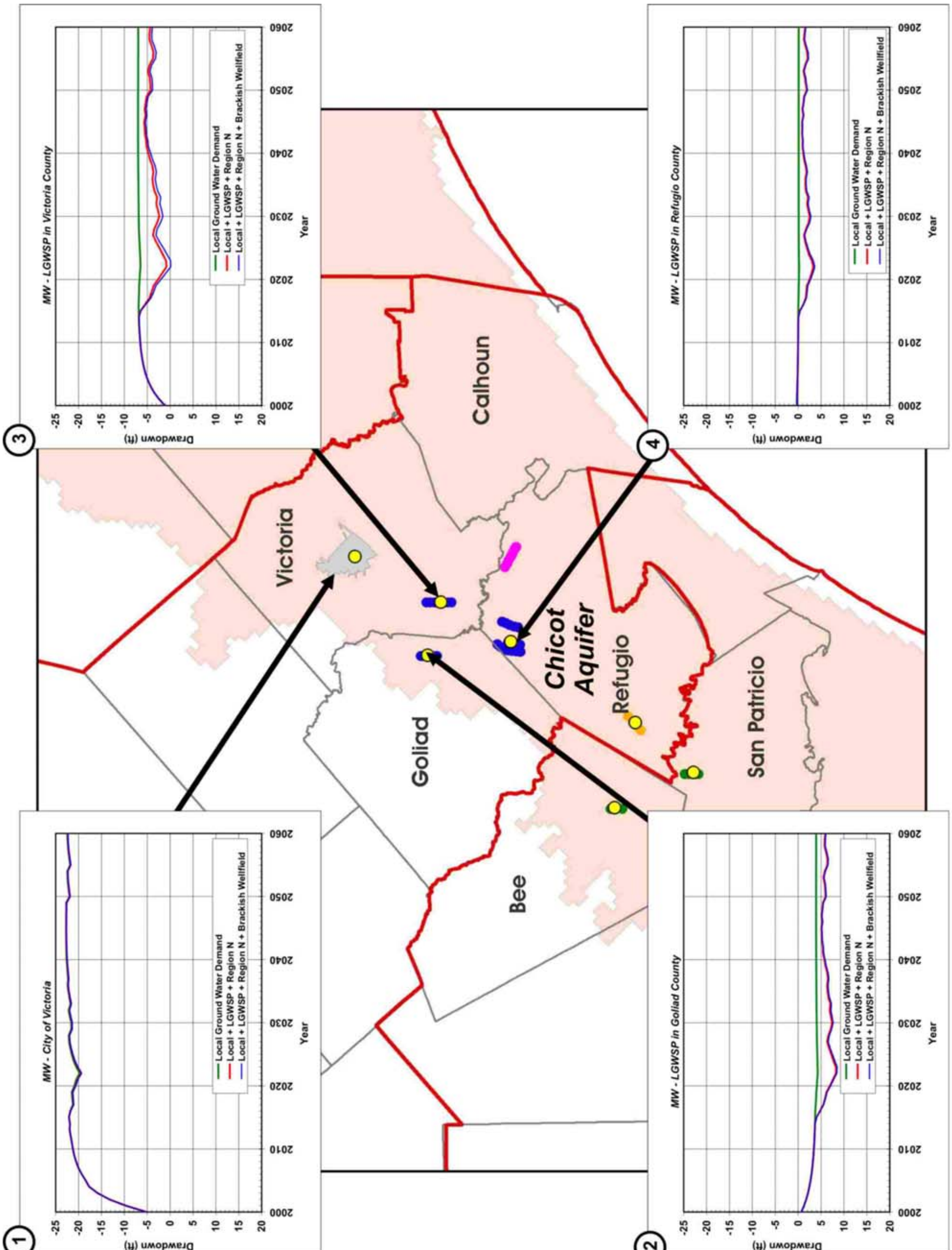


Figure 4C.19-42. Predictive Drawdown Hydrographs for the Chicot Aquifer near Pumping Centers

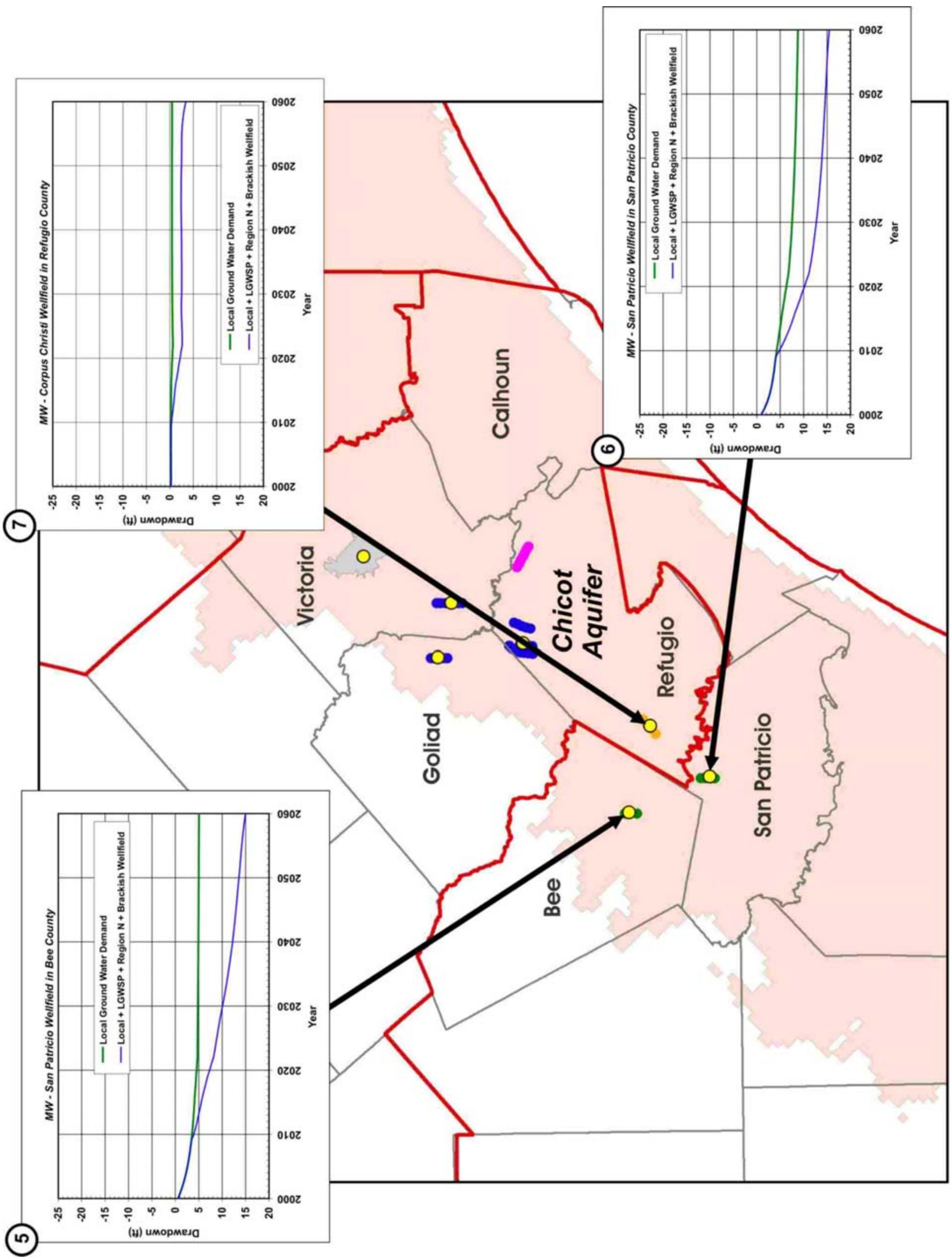


Figure 4C.19-43. Predictive Drawdown Hydrographs for the Chicot Aquifer near Pumping Centers

Graph 7 is in the Corpus Christi well field; this well field comes online in 2056. Drawdown in 2010 to 2055 reflects effects from the San Patricio and the LGWSP well fields. The 2060 additional drawdown from local Chicot Aquifer groundwater levels due all projects is approximately 3 feet.

Figure 4C.19-44 illustrates model-wide drawdown in the Chicot Aquifer throughout the 60-year model run. This figure shows the total drawdown effects from the local groundwater pumping demand and the effects of with Region L and Region N projects in place. The graphs illustrate that Region N and Region L project pumping affects the aquifer slightly near the pumping centers and less so regionally.

4C.19.6 General Head Boundary

Both the partially-penetrating and the fully-penetrating models have a general head boundary (GHB) along the down dip edge of the Chicot Aquifer (Layer 1) to represent hydraulic communication with the part of the aquifer that is under direct influence with the Gulf of Mexico. This representation allows groundwater to flow into or out of the model under a regional hydraulic gradient. None of the other three model layers have GHBs represented on the Gulf Coast side of the model.

The flux across the portion of the Layer 1 GHB immediately down dip of the groundwater project pumping areas (which includes eastern San Patricio County, Aransas County, Refugio County, and western Calhoun County) was calculated and analyzed using the fully-penetrating model. The direction of the model-calculated GHB flux in the groundwater project predictive simulation, with Region L and Region N project pumping (including the LGWSP brackish well field), is consistently *outflow* from the modeled aquifer to the GHB in the down dip direction. The quantity of the flux across this portion of the boundary is about 23,000 acft/yr of outflow from the Chicot Aquifer to the GHB at the height of the simulated drought in 2022. This flux increases to about 25,700 acft/yr of outflow in 2060.

A study of these results along with the aquifer heads (Figures 4C.19-3, 4C.19-36, 4C.19-37, and 4C.19-38), indicate that the outflow to the Layer 1 GHB is lowest during the model-simulated drought, but that the direction of flow across the boundary is consistently down dip even during the drought. With the groundwater flow gradient remaining in the down dip direction even with the project pumping, the analysis implies that salt water intrusion, if any, into the Chicot Aquifer would be negligible. It should be noted that because there is no down dip

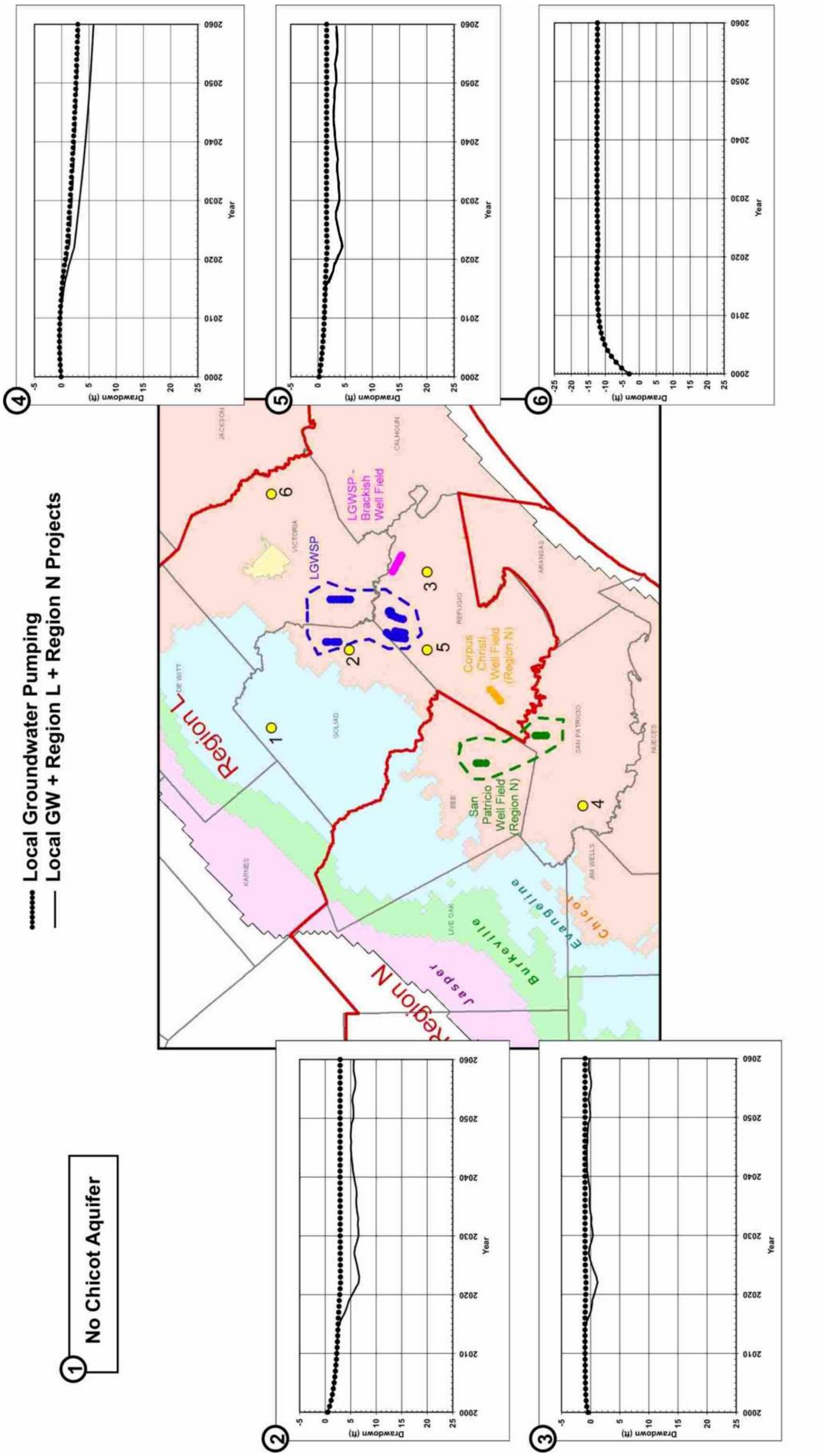


Figure 4C.19-44. Model-Wide Predictive Drawdown Hydrographs in the Chicot Aquifer

GHB in the Evangeline Aquifer model layer where the project pumpage is proposed, this type of analysis cannot be performed for this layer. However, calculated Evangeline Aquifer water levels are higher than mean seal level most all of the time and, as with the Chicot Aquifer, the regional ground water flow direction is toward the Gulf of Mexico, and implies that salt water intrusion, if any, would be negligible.

4C.19.7 Cumulative Changes in Baseflow

Changes in baseflow caused by development of the Central Gulf Coast groundwater is of great interest in the Guadalupe-San Antonio River Basin. Drawdowns in groundwater levels in the aquifer outcrops may result in reduced flow from the aquifers to the streams or increased leakage from the streams to the aquifers. For comparative purposes, the Central Gulf Coast GAMs were used to calculate surface water/groundwater interaction along the two rivers and associated tributaries at three locations including the San Antonio River at Goliad, the Guadalupe River at Victoria, and the Guadalupe River near Tivoli.

In order to estimate these effects, model-calculated fluxes between all of the modeled aquifers (i.e., Chicot, Evangeline, Burkeville, and Jasper) and streams were evaluated for the following two pumping scenarios. The two pumping scenarios included: (1) local ground water demand + Region N projects + LGWSP, and (2) local ground water demand + Region N projects + LGWSP + LGWSP with brackish well field. Calculated cumulative stream-aquifer flux in 2000 (the first year of the simulation and before any project-related pumping), was compared with flux in 2022 (the model-simulated drought), and 2060.

This modeling approach allows incremental stream-aquifer flux contribution from each component of pumpage to be determined separately. Table 4C.19-3 presents the results for predictive stream-aquifer flux for the two pumping scenarios in the streams of major interest.

For the first pumping scenario of local ground water demand + Region N projects + LGWSP projects, the San Antonio River and tributaries upstream of Goliad is calculated to undergo a net reduction in baseflow from 2000 conditions of 2.6 cfs during drought conditions and a net 1.7 cfs gain during average conditions. With the addition of the LGWSP brackish well field in the second scenario, the San Antonio River upstream of Goliad is calculated to undergo a net reduction in baseflow of 2.7 cfs during drought conditions and a net 1.6 cfs gain during average conditions. In general, the streams are losing water to the aquifers during drought conditions and a gaining water from the aquifers during non-drought conditions.

Table 4C.19-3.
Predictive Surface Water/Groundwater Interaction

Scenario	Project	Year	San Antonio River at Goliad: Flux* (cfs)	San Antonio River at Goliad: Δ from 2000* (cfs)	Guadalupe River at Victoria: Flux* (cfs)	Guadalupe River at Victoria: Δ from 2000* (cfs)	Guadalupe River near Tivoli: Flux* (cfs)	Guadalupe River near Tivoli: Δ from 2000* (cfs)
1	Local Groundwater Demand + Region N Projects + LGWSP	2000	+27.1	—	+20.6	—	-14.4	—
		2020 (Drought)	+24.5	-2.6	+33.7	+13.1	-18.7	-4.3
		2060	+28.7	+1.7	+41.5	+20.9	+2.3	+16.8
2	Local Groundwater Demand + Region N Projects + LGWSP + LGWSP with Brackish Well Field	2000	+27.1	—	+20.6	—	-14.4	—
		2022 (Drought)	+24.4	-2.7	+33.4	+12.9	-25.6	-11.2
		2060	+28.7	+1.6	+41.9	+20.8	-0.3	+14.1

Notes:

*Negative flux values indicate that stream is losing flow to the aquifer at the indicated rate. Positive values indicate that aquifers are discharging to the stream.

Under the first scenario, flow in the Guadalupe River and tributaries upstream of Victoria is calculated to undergo a net gain in baseflow from 2000 conditions of 13.1 cfs during drought conditions and a 20.9 cfs net gain during average conditions. Under the second scenario with the LGWSP brackish well field, the baseflow is calculated to undergo a net gain in baseflow of 12.9 cfs during drought conditions and a 20.8 cfs net gain during average conditions. The net gain in baseflow from 2000 conditions is at least partly due to the City of Victoria's current and projected reduction in groundwater use; since less groundwater is pumped, the aquifer is able to contribute more water to the river.

Under the first scenario, baseflow in the Guadalupe River near Tivoli and its tributaries downstream of Goliad and Victoria is calculated to undergo a net reduction in flow from 2000 conditions of 4.3 cfs during drought conditions and a 16.8 cfs net gain during average conditions under the first scenario. Under the second scenario with the LGWSP brackish well field, baseflow flow is calculated to undergo a net reduction in flow of 11.2 cfs during drought conditions and a 14.1 cfs net gain during average conditions. Overall, the streams are losing water to the aquifer during drought conditions and gaining water from the aquifer during non-drought conditions.

4C.19.8 Central Gulf Coast Aquifer Model Results Summary

The local groundwater supply pumping demands modeled with the Partially-Penetrating Model have little effect on regional groundwater levels. The City of Victoria's reliance on ground water has been reduced from historical levels and as a result, the local ground water levels are rebounding.

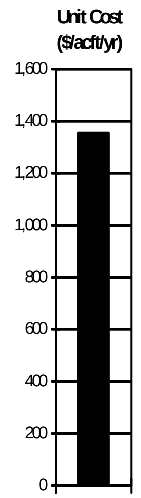
The LGWSP minimally affects local water levels in the Chicot Aquifer. The Region N San Patricio Well field Project in Bee and San Patricio Counties affects drawdowns in the Chicot Aquifer more substantially in San Patricio and Refugio Counties than the LGWSP due to constant pumping.

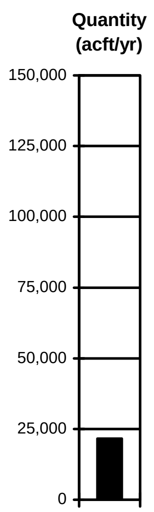
The LGWSP affects local water levels significantly in the Evangeline Aquifer drought during conditions; however, water levels quickly recover when pumping is reduced during non-drought conditions.

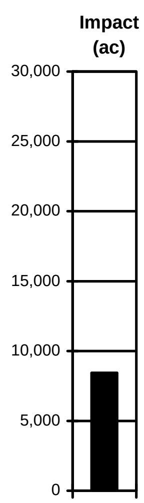
Modeling results indicate that projected local pumpage and pumpage associated with recommended water management strategies in both the Region L and Region N 2006 Regional Water Plans would result in negligible, if any, intrusion into either the Chicot or Evangeline formations within the Gulf Coast Aquifer.

(This page intentionally left blank.)

2006 South Central Texas Regional Water Plan
Water Management Strategy Summary Sheet







Name: **Edwards Aquifer Recharge — Type 2 Projects, Program 2A**

Description: Recharge enhancement structures (dams) located atop the Edwards Aquifer recharge zone on streams that are often dry. Structures impound flood waters that recharge the aquifer by direct percolation with the reservoir surface falling at rates on the order of 2 to 3 ft/day. Planned projects include: Indian Creek (with supplemental transmission system to the Dry Frio River), Lower Frio, Lower Sabinal, Lower Hondo, Lower Verde, San Geronimo, Northern Bexar / Medina County Projects, Salado Creek FRS, Cibolo Dam No. 1, Dry Comal, and Lower Blanco (with supplemental transmission system to the upper San Marcos watershed). The SCTRWPG recommends Program 2C for implementation by year 2020 with potential expansion to include the additional projects in Program 2A by year 2060. The SCTRWPG further recognizes that development of alternative projects at some or all of these sites is consistent with the 2006 Regional Water Plan.

***Decade Needed*:** 2050 – 2060

Cost, Quantity of Water, and Land Impacted

Unit Cost of Water:	**1,355**	**$/acft/yr**	**Raw Water in Aquifer**
Quantity of Water:	**21,577**	**acft/yr[1]**	**Reliability = Firm**
Land Impacted:	**8,448**	**acres**	

[1]Quantity of water based on increase in sustained yield computed using the GWSIM-IV model of the Edwards Aquifer.

Additional Considerations per Regional Water Planning Guidelines

Environmental Factors:

Enhanced springflows support endangered species at Comal & San Marcos Springs. Periodic inundation of reservoir areas may affect endangered arthropods (spiders, beetles, & harvestman) and local terrestrial habitat. Nueces (Indian Creek), Frio, Sabinal, and Blanco sites are located in Ecologically Significant River & Stream Segments per TPWD.

Impacts on Water Resources:

Edwards recharge enhancement increases regional aquifer levels, increases discharge from major springs (e.g., Comal, San Marcos, Leona), and reduces water available to some downstream water rights (e.g., Corpus Christi Reservoir System). Small reductions in Carrizo Aquifer recharge, primarily in the Nueces River Basin.

Impacts on Agricultural & Natural Resources:

Typically higher aquifer levels in Uvalde and Medina Counties.

Other Relevant Factors per SCTRWPG:

EAA aquifer storage and recharge recovery rules. Mitigation of impacts on firm yield of Corpus Christi Reservoir System. Ongoing feasibility studies by USACE in cooperation with SAWS, SARA, GBRA, NRA, EAA, Corpus Christi, TWDB, TPWD, and TCEQ.

Comparison of Strategies to Meet Needs:

Broad range of unit costs among potential recharge programs and individual projects (e.g., Program 2C provides 13,451 acft/yr at a unit cost of $638/acft/yr. The incremental unit cost of new supply between Programs 2C and 2A is $2,543/acft/yr. No conflicts with other recommended water management strategies.

Interbasin Transfer Issues: Not applicable.

Third-Party Impacts of Voluntary Transfers: Not applicable.

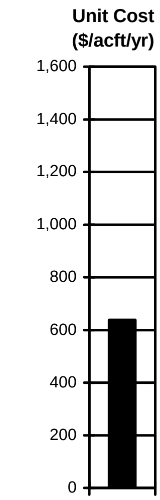
Regional Efficiency:

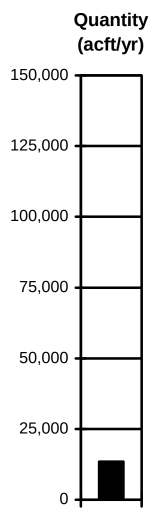
Enhanced Recharge can be recovered using existing wells.

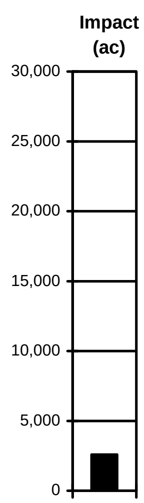
Water Quality Considerations:

Projects in urbanizing watersheds may increase risk of introducing contaminants to aquifer.

2006 South Central Texas Regional Water Plan
Water Management Strategy Summary Sheet







Name: **Edwards Aquifer Recharge — Type 2 Projects, Program 2C**

Description: Recharge enhancement structures (dams) located atop the Edwards Aquifer recharge zone on streams that are often dry. Structures impound flood waters that recharge the aquifer by direct percolation with the reservoir surface falling at rates on the order of 2 to 3 ft/day. Planned projects include: Lower Frio, Lower Sabinal, Lower Hondo, Lower Verde, Salado Creek FRS, and Cibolo Dam No. 1. The SCTRWPG recommends Program 2C for implementation by year 2020 with potential expansion to include the additional projects in Program 2A by year 2060. The SCTRWPG further recognizes that development of alternative projects at some or all of these sites is consistent with the 2006 Regional Water Plan.

***Decade Needed*:** 2010 – 2020

Cost, Quantity of Water, and Land Impacted

Unit Cost of Water:	**638**	**$/acft/yr**	**Raw Water in Aquifer**
Quantity of Water:	**13,451**	**acft/yr[1]**	**Reliability = Firm**
Land Impacted:	**2,595**	**acres**	

[1]Quantity of water based on increase in sustained yield computed using the GWSIM-IV model of the Edwards Aquifer.

Additional Considerations per Regional Water Planning Guidelines

Environmental Factors:

Enhanced springflows support endangered species at Comal & San Marcos Springs. Periodic inundation of reservoir areas may affect endangered arthropods (spiders, beetles, & harvestman) and local terrestrial habitat. Frio and Sabinal sites are located in Ecologically Significant River & Stream Segments per TPWD.

Impacts on Water Resources:

Edwards recharge enhancement increases regional aquifer levels, increases discharge from major springs (e.g., Comal, San Marcos, Leona), and reduces water available to some downstream water rights (e.g., Corpus Christi Reservoir System). Small reductions in Carrizo Aquifer recharge, primarily in the Nueces River Basin.

Impacts on Agricultural & Natural Resources:

Typically higher aquifer levels in Uvalde and Medina Counties.

Other Relevant Factors per SCTRWPG:

EAA aquifer storage and recharge recovery rules. Mitigation of impacts on firm yield of Corpus Christi Reservoir System. Ongoing feasibility studies by USACE in cooperation with SAWS, SARA, GBRA, NRA, EAA, Corpus Christi, TWDB, TPWD, and TCEQ.

Comparison of Strategies to Meet Needs:

Broad range of unit costs among potential recharge programs and individual projects (e.g., Program 2C provides 13,451 acft/yr at a unit cost of $638/acft/yr. The incremental unit cost of new supply between Programs 2C and 2A is $2,543/acft/yr. No conflicts with other recommended water management strategies.

Interbasin Transfer Issues: Not applicable.

Third-Party Impacts of Voluntary Transfers: Not applicable.

Regional Efficiency:

Enhanced Recharge can be recovered using existing wells.

Water Quality Considerations:

Projects in urbanizing watersheds may increase risk of introducing contaminants to aquifer.

4C.20 Edwards Aquifer Recharge — Type 2 Projects

4C.20.1 Description of Water Management Strategy

Two types of recharge enhancement reservoirs have been analyzed and optimized in a series of studies[1,2,3,4,5,6] sponsored by the Edwards Underground Water District and others beginning in 1990. This water management strategy deals with the potential construction of Type 2 projects, which are immediate recharge structures located within the Edwards Aquifer recharge zone. Type 2 structures are, generally speaking, normally dry and impound water for only a few days or weeks following storm events. These structures recharge water very quickly to the aquifer, typically draining at a rate of 2 to 3 feet per day. This large recharge rate minimizes evaporation losses and maximizes recharge.

The approximate location of each of the major Type 2 recharge projects recommended for development is shown in Figure 4C.20-1. Five of the projects are located in the Nueces River Basin and affect inflows to the CCR/LCC System and the Nueces Estuary. These five projects include Indian Creek, Lower Frio, Lower Sabinal, Lower Hondo, and Lower Verde. Other previously identified Type 2 sites in the Nueces River Basin are not recommended because the quantity of enhanced recharge during the drought is extremely small and the associated unit costs are extremely high.

In the Guadalupe-San Antonio River Basin, up to nine new recharge projects are being considered for development or further study. These include San Geronimo, Cibolo Dam No. 1, Dry Comal, Lower Blanco, and up to five small Soil Conservation Service (SCS) type reservoirs in northern Bexar and Medina Counties. Other previously identified recharge enhancement projects in the Guadalupe-San Antonio River Basin recommended for development or further

[1] HDR Engineering, Inc. and Geraghty and Miller, Inc., "Nueces River Basin Regional Water Supply Planning Study, Phase I," Vols. 1, 2, and 3, Nueces River Authority, et al., May 1991.
[2] HDR, "Nueces River Basin Regional Water Supply Planning Study, Phase III – Recharge Enhancement," Nueces River Authority, November 1991.
[3] HDR, "Nueces River Basin, Edwards Aquifer Recharge Enhancement Project, Phase IVA," Edwards Underground Water District, June 1994.
[4] HDR, "Nueces River Basin, Edwards Aquifer Recharge Enhancement Project, Phase IVB, Technical Memorandum, Combined Impacts of Frio, Sabinal, Hondo, and Verde Recharge Enhancement Projects on Downstream Water Rights," December 12, 1995.
[5] HDR, "Guadalupe-San Antonio River Basin Recharge Enhancement Study," Vols. I, II, and III, Edwards Underground Water District, September 1993.
[6] HDR, "Guadalupe-San Antonio River Basin Recharge Enhancement Study Feasibility Assessment," Trans-Texas Water Program, West Central Study Area, Phase II, Edwards Aquifer Recharge Analyses, San Antonio River Authority, et al., March 1998.

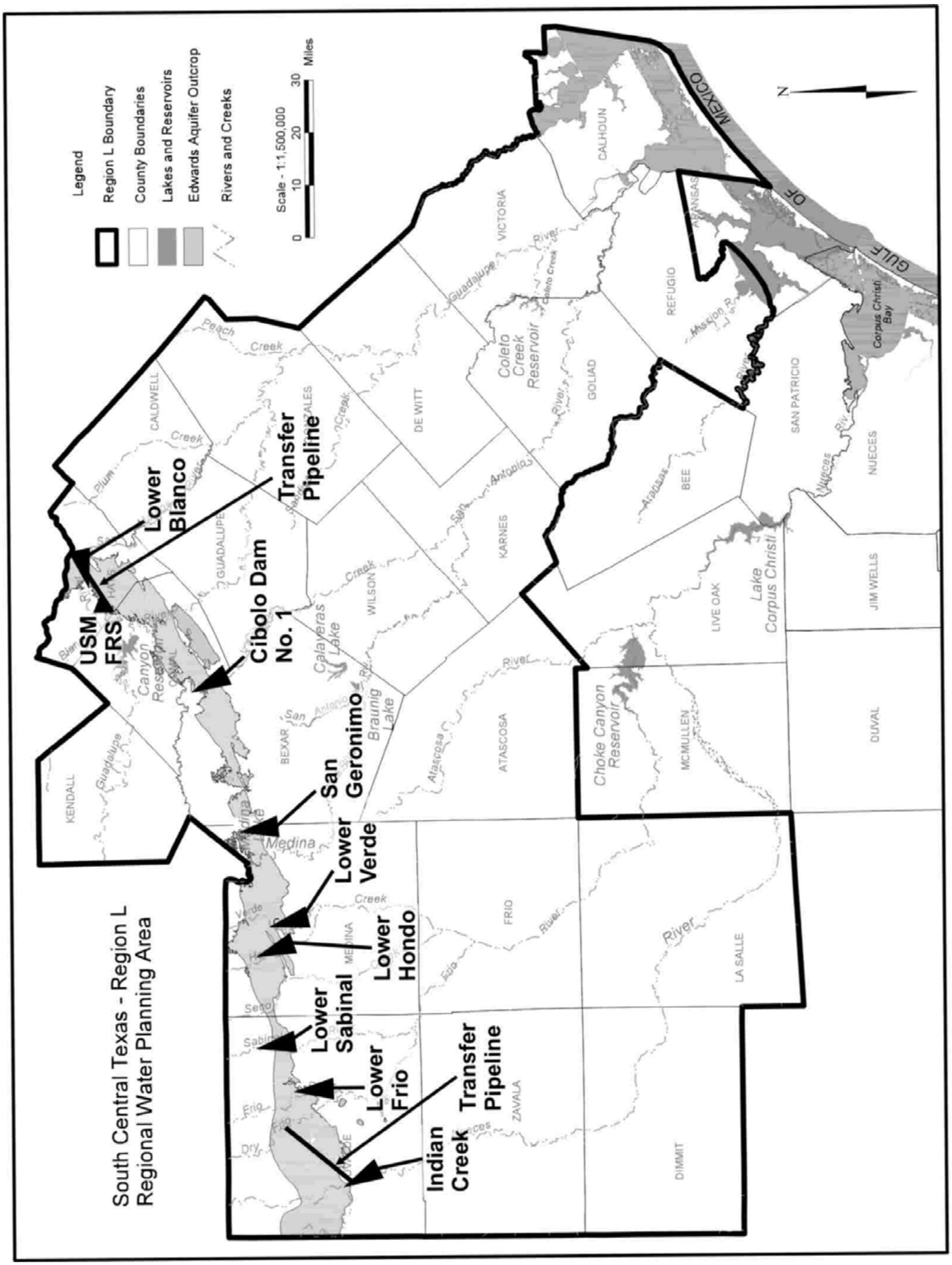


Figure 4C.20-1. Edwards Aquifer Recharge - Type 2 Projects study include projects to modify the outlets on some existing SCS Floodwater Retarding Structures (SCS-FRS) in the Salado Creek watershed. These modifications would either close or restrict the outlets on existing SCS-FRS dams resulting in additional recharge.

The Type 2 projects in the Nueces and Guadalupe-San Antonio River Basins have all been considered in previous studies that included some fairly detailed cost analyses. For these projects, an optimum size has previously been determined for each project. Three Type 2 Programs consisting of up to 14 potential new storage projects and two modifications to existing dams to increase recharge are presented herein. The projects included in each of the three programs are identified below.

4C.20.1.1 Program 2A

- Nueces River Basin
  - Indian Creek (with recharge diversions to Dry Frio River)
  - Lower Frio
  - Lower Sabinal
  - Lower Hondo
  - Lower Verde

- Guadalupe-San Antonio River Basin
  - Lower Blanco (with recharge diversions to San Marcos FRS)
  - Cibolo Dam No. 1
  - San Geronimo
  - Northern Bexar/Medina County Projects
    - Limekiln
    - Culebra
    - Government Canyon
    - Deep Creek
    - Salado Dam No. 3
- Dry Comal
- Salado Creek FRS
    - Modifications to spillways at existing dams 11 and 13B

4C.20.1.2 Program 2B

- Nueces River Basin
  - Lower Frio
  - Lower Sabinal
  - Lower Hondo
  - Lower Verde

- Guadalupe-San Antonio River Basin
  - Lower Blanco (with recharge diversions to San Marcos FRS)
  - Cibolo Dam No. 1
  - San Geronimo
  - Salado Creek FRS
    - Modifications to spillways at existing dams 11 and 13B

4C.20.1.3 Program 2C

- Nueces River Basin
  - Lower Frio
  - Lower Sabinal
  - Lower Hondo
  - Lower Verde
- Guadalupe-San Antonio River Basin
  - Cibolo Dam No. 1
  - Salado Creek FRS
    - Modifications to spillways at existing dams 11 and 13B

The projects in Program 2A would impound a combined maximum recharge pool storage of 170,309 acft and periodically inundate 8,448 acres, as shown in Table 4C.20-1. At the other extreme, Program 2C would impound up to 42,650 acft in the combined recharge storage pools for projects in this program and periodically inundate about 2,595 acres. The South Central Texas Regional Water Planning Group (SCTRWPG) has chosen to recommend Program 2C for implementation by year 2020 with potential expansion to include the additional projects in Program 2A by year 2060. The SCTRWPG further recognizes that development of alternative projects at some or all of these sites (either larger or smaller in capacity) is consistent with the 2006 Regional Water Plan.

4C.20.2 Available Yield

Available yield or recharge enhancement volumes were calculated for the Type 2 structures using the Nueces River Basin Model and the Guadalupe-San Antonio River Basin Model, subject to average and drought conditions. Average conditions represent the average annual recharge enhancement rate for the entire 56-year simulation period (1934 to 1989). Drought conditions represent the average annual recharge enhancement rate for the 10-year period from 1947 through 1956, which is when the most severe drought on record occurred. Analyses of recharge enhancement projects presented in this study were performed honoring all existing water rights to the maximum extent possible, with one exception. This exception involves the water rights of the CCR/LCC System, in which case impacts were not mitigated by releases, but were assumed to be mitigated by remuneration and/or development of additional water supply for the Corpus Christi service area.

Table 4C.20-1.
Summary of Recharge Enhancement Potential for Type 2 Recharge Programs

Type 2 Project Program	Capacity (acft)	Surface Area (acres)	Recharge Enhancement: 1934 to 1989 Average Conditions (acft/yr)	Recharge Enhancement: 1947 to 1956 Drought Conditions (acft/yr)	Reduction in Average Nueces Estuary Inflow (acft/yr)	Reduction in CCR/LCC System Yield (acft/yr)	Reduction in Drought Average Guadalupe Estuary Inflow (acft/yr)
Program 2A	170,309	8,448	134,434	50,032	14,590	4,308	13,269
Program 2B	96,150	4,186	108,003	34,788	11,592	1,355	13,026
Program 2C	42,650	2,595	54,471	10,034	11,592	1,355	500

1 Estuarine inflow reduction and CCR/LCC System yield reductions estimated by the addition of Indian Creek Project impacts from “Edwards Aquifer Recharge Enhancement Project, Phase IVA” and the analysis in footnote 2 below.
2 Estimates of estuarine inflow reduction and CCR/LCC System yield reduction quantities were taken from “Nueces River Basin, Edwards Aquifer Recharge Enhancement Project, Phase IVB, Technical Memorandum, Combined Impacts of Frio, Sabinal, Hondo, and Verde Recharge Enhancement Projects on Downstream Water Rights,” December 12, 1995, prepared by HDR Engineering, Inc.
3 Estimates of drought average (1947 to 1956) estuarine inflow reductions for all Guadalupe-San Antonio River Basin Projects were taken from “Guadalupe-San Antonio River Basin Recharge Enhancement Study Feasibility Assessment,” West Central Study Area, Trans-Texas Water Program, Phase II, Edwards Aquifer Recharge Analysis.

For the Type 2 Recharge Program 2A, recharge could be enhanced by 134,434 acft/yr for average conditions and 50,032 acft/yr for drought conditions as shown in Table 4C.20-1. The impact on the CCR/LCC System totals 4,308 acft/yr for the Type 2 Program 2A, which represents about 2 percent of the system firm yield. Estimates indicate that Type 2 Recharge Program 2B could enhance recharge by 108,003 acft/yr for average conditions and 34,788 acft/yr during drought. Program 2B impacts CCR/LCC System yield by 1,355 acft/yr (less than 1 percent). Program 2C could enhance recharge in the Nueces and Guadalupe-San Antonio River Basins by 54,471 acft/yr and 10,034 acft/yr, during average and drought conditions, respectively. Impacts to CCR/LCC System yield under Program 2C are the same as under Program 2B.

Application of the Consensus Criteria for Environmental Flow Needs (CCEFN) for reservoir pass-throughs for instream flows was included in this analysis for the Type 2 recharge projects. The only potential recharge dams that required reservoir pass-throughs were Indian Creek and Lower Blanco. Tables 4C.20-2 and 4C.20-3 contain the streamflow statistics used to

Table 4C.20-2
Daily Naturalized Streamflow Statistics for
Indian Creek Edwards Recharge - Type II Project

Month	***Median Flows - Zone 1 Pass-Through Requirement (cfs)***	***25th Percentile Flows - Zone 2 Pass-Through Requirement (cfs)***
January	25.2	22.2*
February	23.7	22.2*
March	22.2*	22.2*
April	23.2	22.2*
May	26.2	22.2*
June	28.2	22.2*
July	29.2	22.2*
August	28.2	22.2*
September	24.7	22.2*
October	30.8	22.2*
November	30.2	22.2*
December	27.2	22.2*
Zone 3 Pass-Through Requirement (cfs)		22.2
** Zone 3 Pass-Through Requirement exceeds 25th Percentile Flow and Median Flow.*		

Table 4C.20-3
Daily Naturalized Streamflow Statistics for
Lower Blanco Edwards Recharge - Type II Project

Month	***Median Flows - Zone 1 Pass-Through Requirement (cfs)***	***25th Percentile Flows - Zone 2 Pass-Through Requirement (cfs)***
January	40.3	14.6*
February	51.4	14.6*
March	45.4	14.6*
April	67.6	15.1
May	76.1	23.2
June	68.1	27.7
July	37.3	14.6*
August	16.6	14.6*
September	24.2	14.6*
October	29.2	14.6*
November	29.2	14.6*
December	40.3	14.6*
Zone 3 Pass-Through Requirement (cfs)		14.6
** Zone 3 Pass-Through Requirement exceeds 25th Percentile Flow and Median Flow.*		

apply CCEFN for Indian Creek and Lower Blanco, respectively. The criteria were not significant at other sites because, under normal weather conditions, the streams on which these sites are located do not contribute flows downstream of the recharge zone. The maximum impact on the average inflow to the Nueces Estuary due to the five Nueces River Basin projects (Program 2A) is a reduction of about 14,590 acft/yr, or about 6 percent. The impact of the remaining sites on the average inflow to the Guadalupe Estuary (as measured at the Guadalupe River Saltwater Barrier) would be a reduction of about 13,300 acft/yr, or about 1 percent under Program 2A during drought (1947 to 1956). The impact of Program 2C on average inflows to the Nueces Estuary is about 11,590 acft/yr, or about 4.5 percent, and to the Guadalupe Estuary, is 500 acft/yr.

Once monthly recharge enhancement amounts were computed for each potential project, they were added to the baseline recharge for the GWSIM-IV Model of the Edwards Aquifer at the spatial locations representing the proposed recharge enhancement projects. Figure 4C.20-2 shows the Edwards Aquifer GWSIM-IV Model cell grid with an overlay of the streams and major reservoirs in the model area. Also shown in this figure are the approximate locations of the recharge enhancement projects modeled. Recharge enhancement estimates from the surface water models for Program 2A, Program 2B, and Program 2C were distributed into the appropriate recharge zone cells in the GWSIM-IV Model. Application of the GWSIM-IV Model provides a basis for determining additional groundwater that could potentially be withdrawn under a recharge recovery permit[7] for each Type 2 Recharge Enhancement Program (Appendix C). It is noted, however, that rules governing recharge recovery have yet to be applied at this scale by the Edwards Aquifer Authority. A summary of the sustained yield pumpage increase associated with each Type 2 Recharge Enhancement Program is presented in Table 4C.20-4. Quantification of an increase in sustained yield of the Edwards Aquifer during the drought of record provides a means for direct comparison of recharge enhancement strategies with surface water supply strategies under TWDB rules for regional water supply planning.

[7] HDR, "Introduction to Technical Application Requirements for Artificial Recharge Contracts and Recharge Recovery Permits," Edwards Aquifer Authority, December 1998.

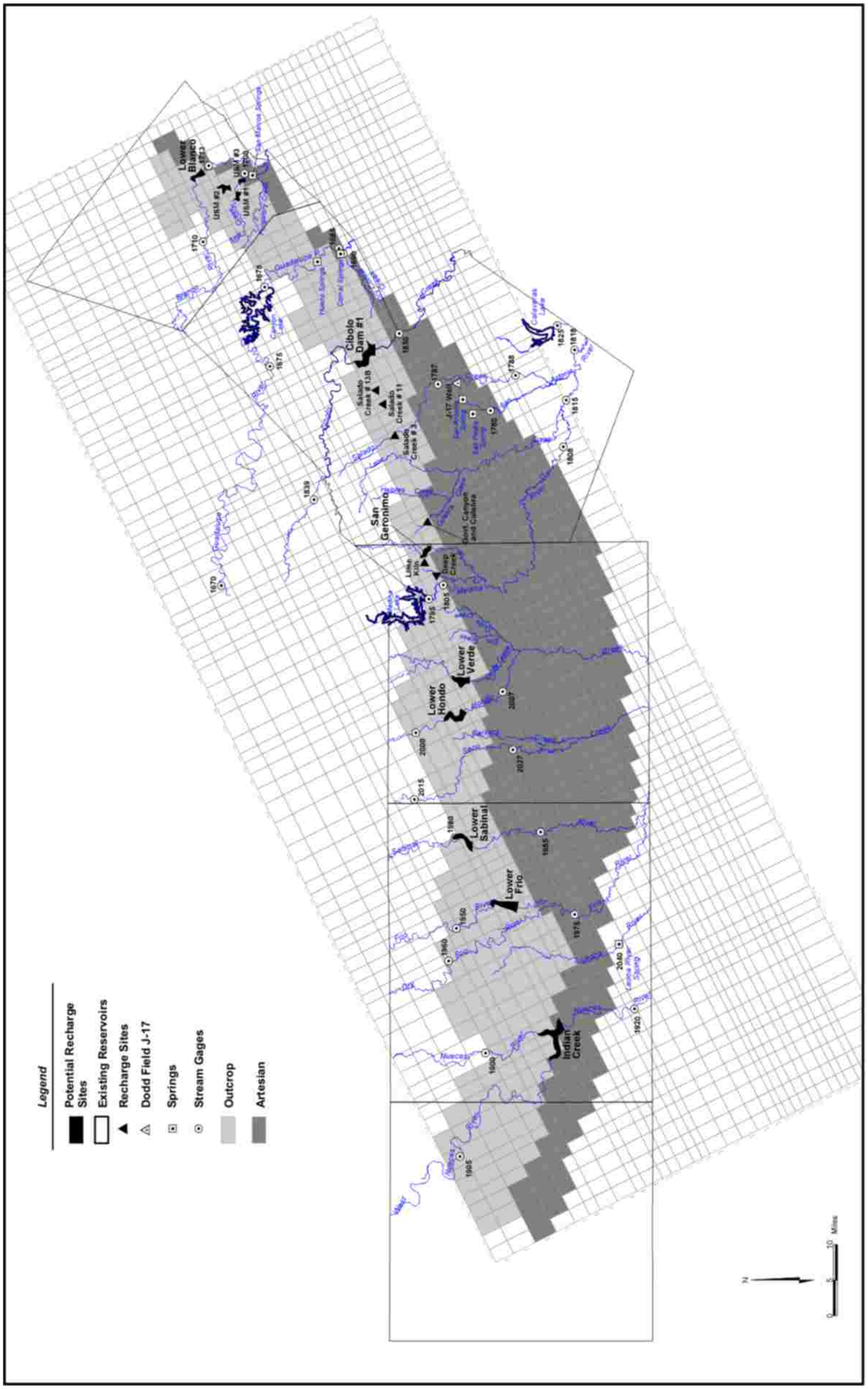


Figure 4C.20-2. Edwards Recharge — Type 2 Projects

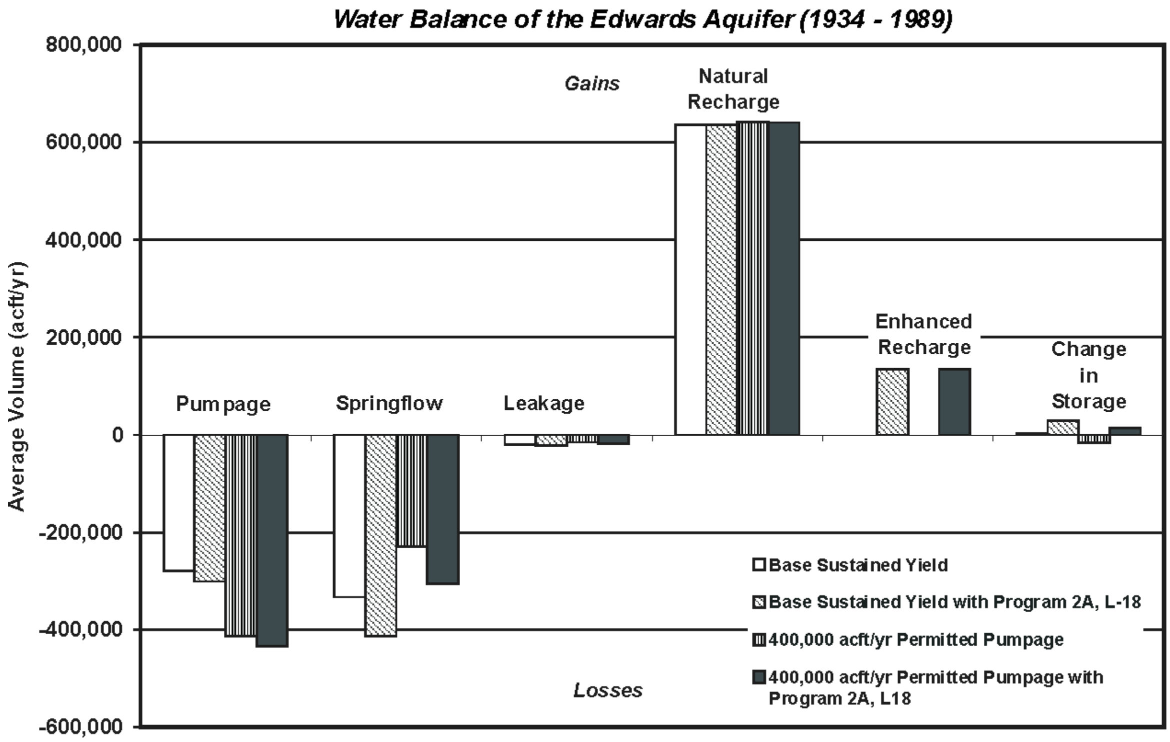
Figure 4C.20-3 summarizes the results of the GWSIM-IV Model runs used to determine the change in sustained yield associated with enhanced recharge for Program 2A. With long-term average enhanced recharge of 134,434 acft/yr, the sustained yield pumpage was found to increase by 21,577 acft/yr (16 percent of the average annual enhancement). The majority of the average annual recharge enhancement becomes springflow. As shown in Table 4C.20-4, 80,189 acft/yr (60 percent) of the 134,434 acft/yr recharge enhancement becomes increased springflow. This increase in springflow is shown in the lower chart in Figure 4C.20-3. This chart shows the Comal Springs flow patterns under the 400,000 acft/yr management plan pumpage with and without a recharge recovery permit pumpage of 21,577 acft/yr. As seen in this figure, the close proximity of the Lower Blanco and Cibolo Dam No. 1 recharge projects to Comal and San Marcos Springs serve to enhance springflow more than increase dependable supply for municipal pumpage.

Table 4C.20-4.
Summary of Sustained Yield Enhancement for Type 2 Reservoir Programs

Type 2 Project Program	*Recharge Enhancement*		*Sustained Yield Pumpage Increase (acft/yr)*	*Increase in Springflow (acft/yr)*
	1934 to 1989 Average Conditions	*1947 to 1956 Drought Conditions*		
Program 2A	134,434	50,032	21,577	80,189
Program 2B	108,003	34,788	15,980	69,971
Program 2C	54,471	10,034	13,451	24,401

[1] Sustained yield increase based on comparison of GWSIM-IV Model runs in which aquifer pumpage was maximized while maintaining a minimum flow from Comal Springs of 60 cfs in one and only one month with and without recharge enhancement from the associated Type 2 Program.

Program 2B was analyzed in a similar fashion and the results indicate similar increases, on a percentage basis, to sustained yield and springflow. Under Program 2B, 15,980 acft/yr (15 percent) of the 108,003 acft/yr average annual recharge enhancement is potentially available for recovery on a firm basis, while 69,971 acft/yr (65 percent) becomes increased springflow. The primary difference between Programs 2A and 2B is the exclusion of the Indian Creek recharge project in Program 2B. The Lower Blanco and Cibolo Dam No. 1 projects remain and thus Comal and San Marcos springflow enhancement remains high. The results for Program 2B are shown in Figure 4C.20-4.



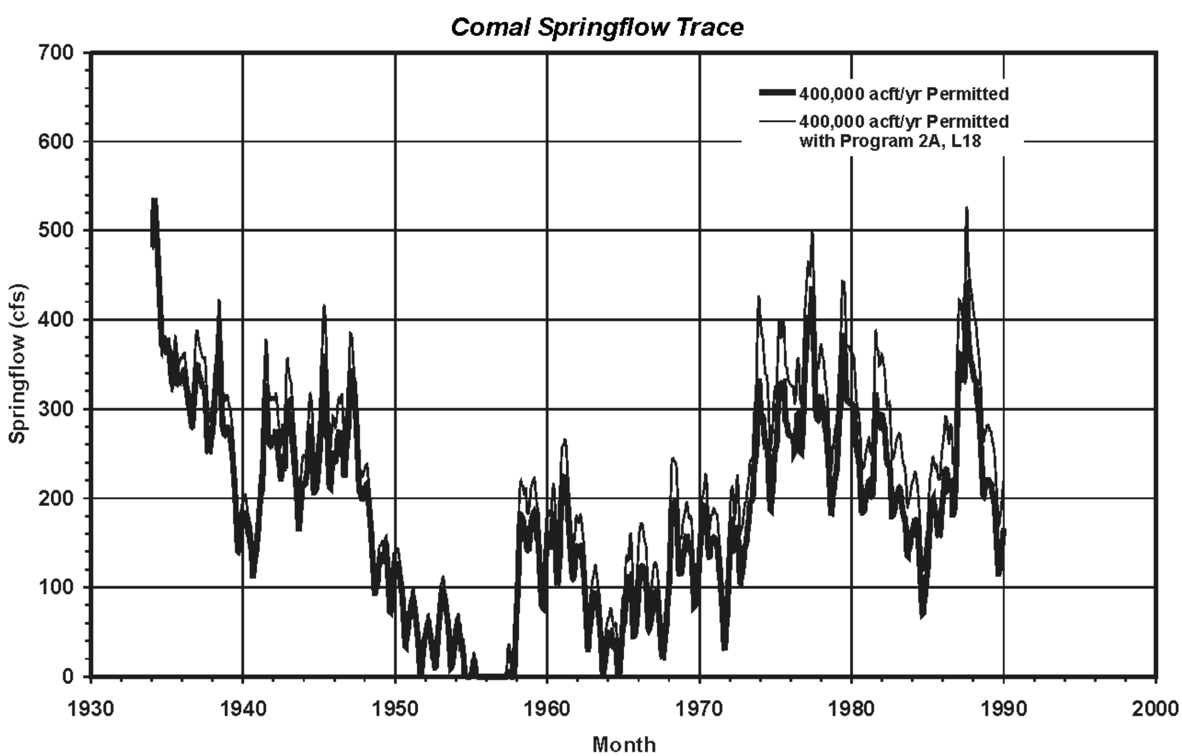
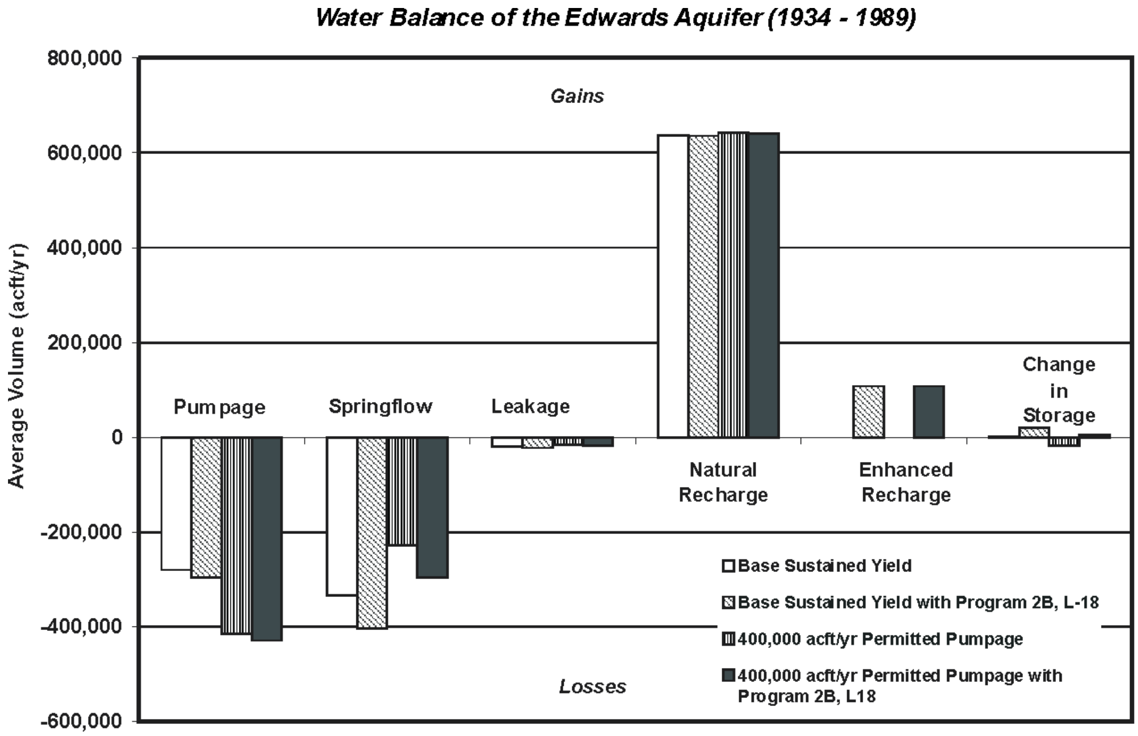


Figure 4C.20-3. Enhanced Recharge from Type 2 Recharge Projects — Program 2A



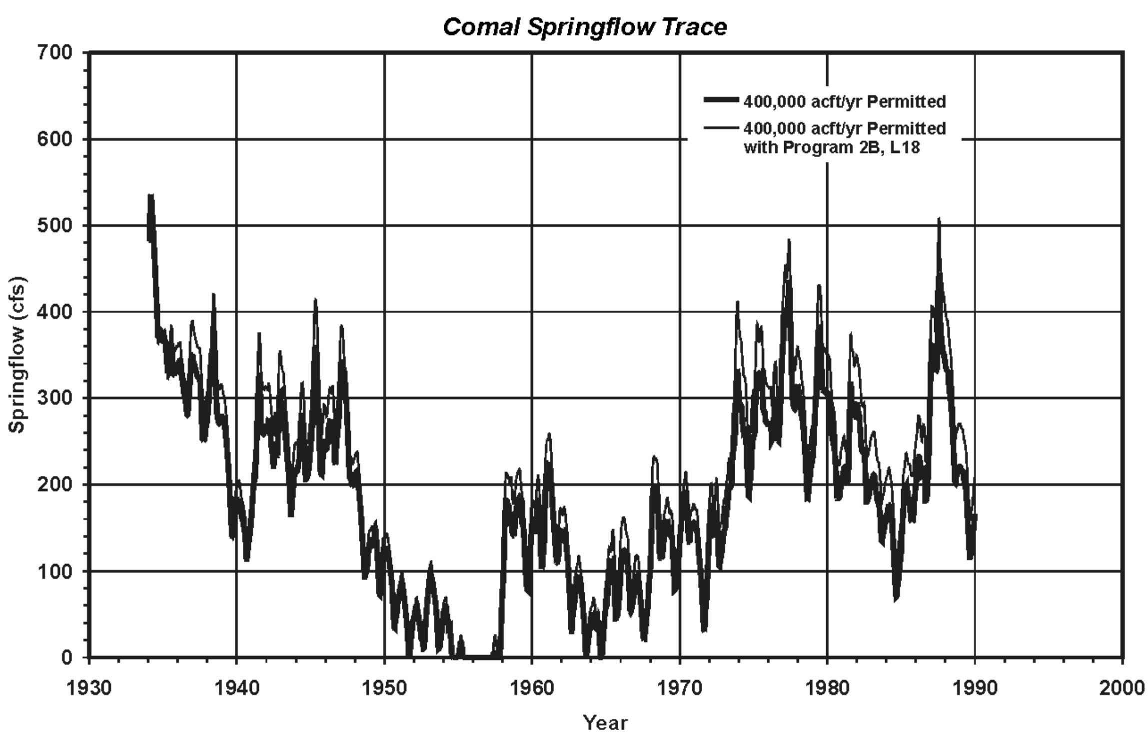


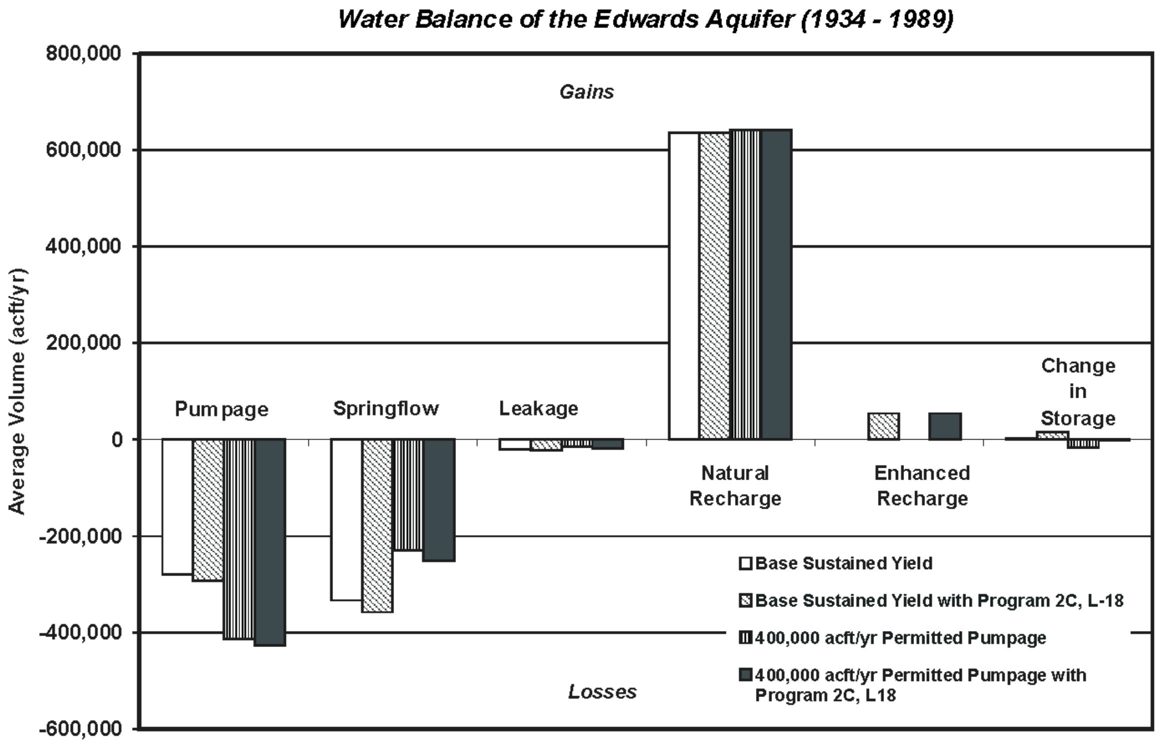
Figure 4C.20-4. Enhanced Recharge from Type 2 Recharge Projects — Program 2B

In Program 2C, the Indian Creek, Lower Blanco, and San Geronimo recharge enhancement projects were removed from the program. As shown in Table 4C.20-4 and Figure 4C.20-5, the increase in sustained yield pumpage of the aquifer is 13,451 acft/yr, approximately 25 percent of the average annual recharge enhancement. This is the only program considered herein with a sustained yield greater than the drought average recharge enhancement. Figure 4C.20-5 and Table 4C.20-4 also indicate that the removal of the Lower Blanco project from the Program 2C analysis decreased the percentage of average annual enhancement that became increased springflow. For Program 2C, 24,401 acft/yr (or 45 percent) of the annual average recharge enhancement becomes springflow. For these reasons, Program 2C appears to be, in a hydrologic sense, the most efficient Type 2 recharge project enhancement program.

Potential Edwards Aquifer recharge enhancement projects could negatively impact natural recharge of the Carrizo-Wilcox Aquifer. Previous studies[8] have estimated recharge to the Carrizo-Wilcox Aquifer by breaking recharge into three components: baseflow recharge in the stream, flood flow recharge in overbanks of the stream, and areal recharge in the tributaries and soils in the watershed outside the main channel. Of these three components, flood flow recharge is the component most likely to be negatively impacted by recharge dams on the Edwards Aquifer outcrop, upstream of the Carrizo-Wilcox outcrop. Flood flow recharge is defined as the recharge that occurs along the main channel during flood events due to the inundation of overbanks adjacent to the river. Previous estimates of total recharge in the Winter Garden Area[9] (the Carrizo-Wilcox from the Rio Grande to the San Marcos River) tabulated flood flow recharge to the Carrizo-Wilcox as approximately 25 percent (51,500 acft/yr) of the total average annual recharge to the aquifer. Total average annual recharge in the Winter Garden Area was estimated to be 207,700 acft/yr.

Average annual flood flow recharge in the area was estimated to be 51,500 acft/yr, of which 17,700 acft/yr occurs on streams which could potentially be impacted by Type 2 Edwards Aquifer recharge enhancement projects. Therefore, in the most extreme case (no flood flow recharge to the Carrizo-Wilcox downstream of potential Type 2 projects) average annual Carrizo-Wilcox natural recharge could be reduced by about 8.5 percent (17,700 ÷ 207,700) under Program 2A. Similarly, under Program 2B, the removal of an Edwards Project on the Nueces

[8] LBG-Guyton Associates and HDR Engineering, Inc., "Interaction between Ground Water and Surface Water in the Carrizo-Wilcox Aquifer," Texas Water Development Board, August 1998.
[9] Ibid.



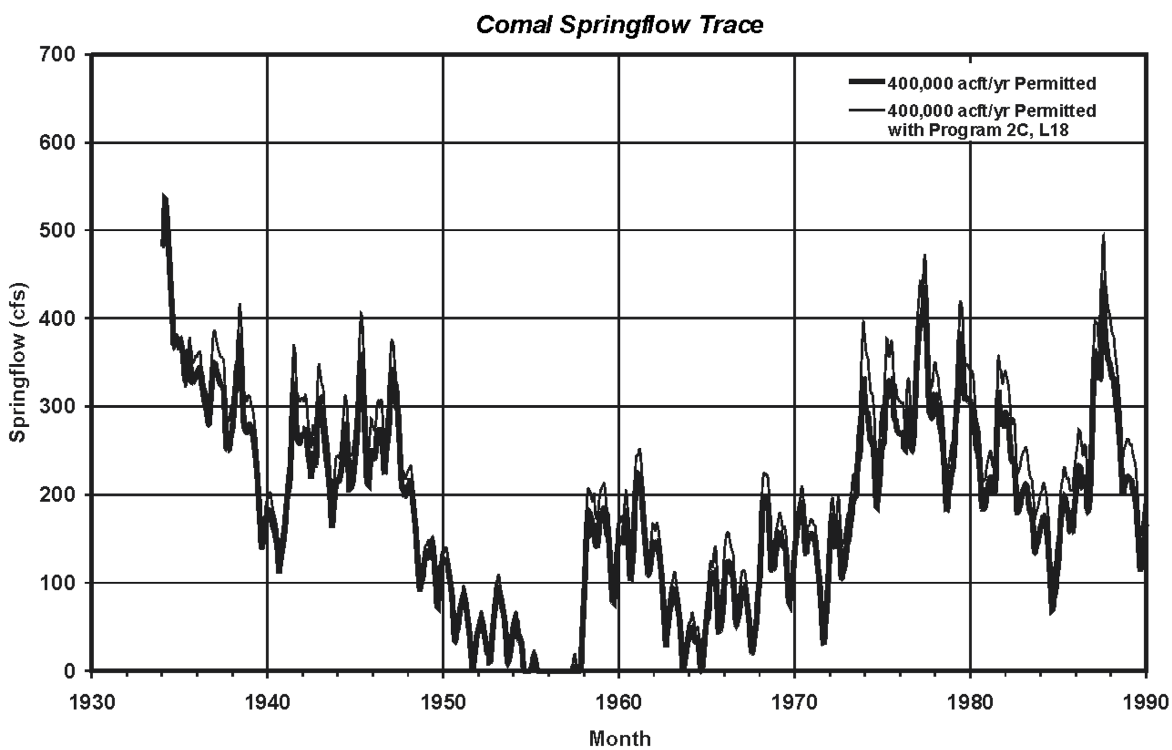


Figure 4C.20-5. Enhanced Recharge from Type 2 Recharge Projects — Program 2C

River would decrease the potential impact to Carrizo-Wilcox recharge down to 5 percent of the total average annual recharge. Likewise, Program 2C could cause a decrease in Carrizo-Wilcox average annual recharge of at most 4 percent. It should be noted that these estimates of impacts, while relatively small, are essentially the maximum attainable assuming the Edwards Aquifer recharge projects completely control all floods on their respective streams. The proposed Type 2 projects, however, are not large enough to control floods to this extent. Therefore, impacts to Carrizo-Wilcox recharge across the region will most certainly be considerably less than the potential impacts presented above.

4C.20.3 Environmental Issues

Type 2 reservoirs are immediate recharge (direct percolation) structures that drain from the bottom of the reservoir into the recharge zone until the entire volume is exhausted, usually within a period of less than 1 month. Type 2 reservoirs are intended to impound flows that would have otherwise passed across the recharge zone.

Suitable sites for the Type 2 reservoirs are located in the area encompassing the headwaters of the Nueces River Basin along the southern margin of the Edwards Plateau in Medina and Uvalde Counties, and the headwaters of the San Antonio and Guadalupe rivers along the southeastern margin of the Edwards Plateau in Bexar, Comal and Hays Counties, respectively (Figure 4C.20-1). There are three Type 2 reservoir sites in Uvalde County (Indian Creek, Lower Frio and Lower Sabinal), five Type 2 reservoir sites in Medina County (Lower Hondo, Lower Verde, San Geronimo, Deep Creek, and Limekiln), four Type 2 reservoir sites in Bexar County (Culebra, Government Canyon, Salado Dam #3, and Cibolo Dam #1), one Type 2 reservoir site in Comal County (Dry Comal), and one Type 2 reservoir site in Hays County (Lower Blanco). In addition, there are proposals for modifying outlets on existing floodwater retarding structures in the Salado Creek watershed. Portions of the Frio, Sabinal, and Blanco Rivers have been designated by Texas Parks and Wildlife Department as Ecologically Significant River and Stream Segments.

All of the Type 2 recharge project sites are located near the southern edge of Omernik's Central Texas Plateau Ecoregion and the corresponding ecotones of Gould, Blair and Correll and

Johnston.[10,11,12,13] Downstream of the Edwards recharge area, the streams enter Omernik's Texas Blackland Prairie or South Texas Plains ecoregions.

The terrestrial habitat impacts of the Type 2 reservoirs will depend on the amount of clearing done, frequency of inundation, and the rapidity of pool drainage following capture of run-off. Operation of a Type 2 recharge structure on Parker's Creek in Medina County for 20 years has resulted in little or no impact to terrestrial vegetation beyond an approximately 20 acre cleared area immediately upstream of the dam. Conservation (recharge) pool levels and major types of habitat that would be inundated as a result of operation of the Type 2 reservoirs being studied here are listed in Table 4C.20-5.

Table 4C.20-5.
Habitats Affected by Operation of Type 2 Recharge Reservoirs (L-18)

Reservoir	Recharge Pool[1] (acres)	Grassland (%)	Brush (%)	Developed (%)	Crops (%)	Woodlands (%)	Wetland (acres)
Indian Creek	3,657	20%	80%				10.4
Lower Frio	1,099	20%	80%				7.4
Lower Sabinal	454						
Lower Hondo	232	70%				30%	5.5
Lower Verde	334	3%				97%	8.2
San Geronimo	183		45%			40%	5
Government Canyon	216	No information available					
Cibolo Dam #1	476	10%				40%	50
Dry Comal	265[E]	5%	10%	5%	50%	20%	10

[1] Corresponds to conservation pool of a conventional reservoir.
E = estimated

Because Type 2 reservoirs are immediate recharge (direct percolation) structures that drain directly into karst features (fractures, holes, and/or caves) present below the stream channel, disturbance of the local karst system and its fauna is a possibility. The fauna inhabiting these caves are usually small in both species diversity and population size, and are adapted to relatively stable physical habitats, which presumably makes them particularly sensitive to disturbances outside of the natural regime. Both terrestrial and aquatic communities are

[10] Omernik, James M., "Ecoregions of the Conterminous United States," Annals of the Association of American Geographers, 77(1) pp. 118-125, 1987.
[11] Correll, D.S., and M.C. Johnston, "Manual of the Vascular Plants of Texas," Texas Research Foundation, Renner, Texas, 1979.
[12] Blair, W. F., "The Biotic Provinces of Texas," Texas Journal of Science 2(1): pp. 93-117, 1950.
[13] Gould, F.W., "The Grasses of Texas," Texas A & M University Press, College Station, Texas, 1975.

extensive in the karst openings associated with the Edwards limestone, and significant threats to these habitats presently exist as a result of human activities in many areas, including northern Bexar County.[14,15]

The extent of intermittently flooded karst zones that would be affected hydrologically by the proposed Type 2 structures is unknown. The extent to which these zones are inhabited by protected species is largely limited to Bexar County, but similar Karst communities exist throughout the Edwards recharge area. The effects of hydrologic changes on resident Karst communities will depend on the extent, frequency, and duration of inundation. While karst openings in stream beds are generally devoid of established terrestrial communities as a result of flooding, scour and deposition, Karst openings in the vicinity of the recharge structures that presently experience periodic flooding may be inundated for longer periods, or experience an increase in the maximum elevation to which the water rises following a runoff event.

The types of dissolved and suspended materials entering the Edwards aquifer are not expected to be altered by the Type 2 reservoirs. As only brief impoundment and immediate recharge will take place there will be no opportunity for thermal stratification to set up or for oxidation of entrained organic material to deplete dissolved oxygen levels. The presence of the dams will increase sediment deposition in the inundated reach upstream of the dam. Openings in the stream bank would be exposed to successively smaller organic matter that could alter the oligotrophic conditions typical of protected karst species.

Operation of the recharge structures will result in additional yield to be available for human use, but modeling has shown a large proportion (averaging 45-65% depending on the projects constructed) of the recharged water appearing as enhanced Edwards springflow. Modeling also demonstrated springflow enhancement even during the drought of record. Operation of the recharge structures will also result in a reduction in the frequency and magnitude of flood flows that make it completely across the recharge zone. Presumably, this will affect channel morphology downstream of the recharge dam as a result of flood peak and frequency reduction. On the other hand, interception of the bed load in the recharge reservoir will tend to mitigate the extent of aggradation in the stream channel below the dam and sediment transport across the recharge zone. Effects on downstream aquatic communities will be mediated through the extent to which perennial aquatic habitats (pools and flowing reaches)

[14] Ibid.

[15] Longley, G., "The Edwards Aquifer: Earth's Most Diverse Ground Water Ecosystem?" International. J. Speleol. 11:123-128, 1981.

persist in the stream reaches immediately below the recharge zone. The upstream limits of perennial pools or flowing reaches may be expected to decrease to some extent as a result of recharge structure operation.

The USFWS lists as endangered several new species of invertebrates with limited distributions in caves of northern Bexar County (Table 4C.20-6). These species are identified as inhabiting specific caves, although an effort is being made to identify additional habitat areas. All of the Type 2 recharge sites are in areas that have a potential for caves containing endangered species.[16]

Table 4C.20-6
Arthropods Listed as Endangered by USFWS

Common Name	*Scientific Name*	*Summary of Habitat Preference*	*Cave Location Known to Exist*	*County*
Government Cave Spider	*Neoleptoneta microps*	Small, eyeless or essentially eyeless troglobitic spider; karst features in N and NW Bexar Co.	Government Canyon Bat Cave	Bexar
Cokendolpher Cave Harvestman	*Texella Cokendolpheri*	Small, eyeless or essentially eyeless troglobitic harvestman; karst features in N and NW Bexar Co.	Robber Baron Cave	Bexar
Madla's Cave Spider	*Cicurina madla*	Small, eyeless or essentially eyeless troglobitic spider; karst features in N and NW Bexar Co.	Madla's Cave	Bexar
Govt. Canyon Bat Cave Meshweaver	*Cicurina vespera*	Small, eyeless or essentially eyeless troglobitic spider; karst features in N and NW Bexar Co.	Bracken Bat Cave	Bexar
Robber Baron Cave Spider	*Cicurina baronia*	Small, eyeless or essentially eyeless troglobitic spider; karst features in N and NW Bexar Co.	Robber Baron Cave	Bexar
Braken Bat Cave Meshweaver	*Cicurina venii*	Small, eyeless or essentially eyeless spider; karst features in N and NW Bexar Co. troglobitic	Government Canyon Bat Cave	Bexar
Ground Beetle 1	*Rhadine exilius*	Small, essentially eyeless ground beetle; karst features in N and NW Bexar Co.	John Wagner Ranch Cave No. 3 (Marnock Cave)	Bexar
Ground Beetle 2	*Rhadine infernalis*	Small, essentially eyeless ground beetle; karst features in N and NW Bexar Co.	Government Canyon Bat Cave, Cave of the Woods, Genesis Cave, Helotes Blowhole, Isopit, Kamikaze Cricket Cave, Poison Ivy Pit, and Wurzbach Cave	Bexar
Helotes Mold Beetle	*Bastrisodes venyivi*	Small, essentially eyeless mold beetle; karst features in N and NW Bexar Co.	Helotes Hilltop Cave	Bexar

[16] Ibid.

Government Canyon Bat Cave is located in the immediate vicinity of the potential recharge site on that stream. Although the known opening of this cave is located well above the impoundment elevation, the depth to which *Cicurina venii*, habitat extends is not known, and additional site surveys would be required to determine whether it might be affected by an increase in the duration of inundation events, or by an increase in the maximum inundation elevation within the cave. On-site surveys of the reservoir and surrounding areas and mitigation or relocation of the project may be required if caves with protected species are found and will be affected by project development. Government Canyon, including the Government Canyon Bat Cave site, is the location of a new State park. The Government Canyon State Park plan includes environmental resource preservation, a preserve for nesting Golden-Cheeked Warblers and Black-Capped Vireos, and some recreational facilities. Natural recharge in the canyon may not conflict with preserving the area's environmental resources and the park development plan, although extensive dam construction may conflict.

Protected and threatened species known or thought to occur in the study areas of Uvalde, Bexar, Hays, Comal, and Medina Counties are listed in Table 4C.20-7. The Wildlife Science Research and Diversity maps, which are maintained by TPWD, do report the occurrence of endangered, threatened, or rare species near the proposed Type 2 projects. The Lower Frio recharge project area includes occurrences of the endangered Black-capped Vireo. Black-capped Vireos are insectivorous songbirds that nest in low shrubland thickets where vegetation extends to ground level. Four rare plants including Dark Noseburn (*Tragia nigricans*), Bracted Twistflower (*Strepthanthus bracteatus*), Texas Largeseed Bittercress (Cardamine macrocarpa var texana) and Comal Nakedwood (*Colubrina stricta*) are also found within this area. Areas near the Lower Sabinal recharge project include habitat preferred by the Black-capped Vireo. The Lower Hondo project area has a number of occurrences of the Texas Mock Orange (*Philadelphus texensis*). The Golden-cheeked Warbler (*Dendroica chrysoparia*) a species listed as endangered is found within the area of the Lower Verde project. Golden-cheeked Warblers prefer habitat consisting of mature oak-juniper woodlands located along steep escarpments and canyons. Occurrences of significant species around the San Geronimo site include Bracted Twistflower, (*Stretanthus bracteatus*), Texas Mock Orange (*Philadelphus texensis*), and Golden-cheeked Warbler (*Dendroica chrysoparia*).

Table 4C.20-7.
Important Species* Having Habitat or Known to Occur in Counties Potentially Affected by Edwards Aquifer Recharge – Type 2 Projects (L-18)

Common Name	Scientific Name	Impact Value	Multiplier Based on Status	Adjusted Impact	Summary of Habitat Preference	Listing Entity: USFWS[1]	Listing Entity: TPWD[1]	Potential Occurrence in County
American Peregrine Falcon	*Falco peregrinus anatum*	0	3	0	Open country; cliffs	DL	E	Nesting/Migrant
Arctic Peregrine Falcon	*Falco peregrinus tundrius*	0	2	0	Open country; cliffs	DL	T	Nesting/Migrant
Balcones Cave Amphipod	*Stygobromus balconies*	0	1	0	Found in cave pools.			Resident
Big Red Sage	*Salvia penstemonoides*	1	1	1	Moist Creek and stream bed edges; historic; introduced in native plant nursery trade			Resident
Big Free-tailed Bat	*Nyctinomops macrotis*	0	1	0	Species prefers to roost in cracks in canyon walls.			Resident
Black Bear	*Usus americanus*	1	2	2	Mountains, broken country, woods, brushlands, forests	T/SA; NL	T	Resident
Black-capped Vireo	*Vireo atricapillus*	1	3	3	oak-juniper woolands with distinctive patchy, two-layered aspect; shrub and tree layer with open, grassy spaces	LE	E	Nesting/Migrant
Black Spotted Newt	*Notophthalmus meridionalis*	1	2	2	Found in wet or sometimes wet areas, such as arroyos, canals, ditches, or shallow depressions; Gulf Coastal Plain of the San Antonio River		T	Resident
Blanco Blind Salamander	*Eurycea robusta*	0	2	0	Troglobitic, water-filled subterranean caverns, may inhabit deep levels of Balcones Aquifer		T	Resident
Blanco River Springs Salamander	*Eurycea pterophila*	0	1	0	Subaquatic, springs and caves in the Blanco River drainage in Blanco, Hays and Kendall			Resident
Blue Sucker	*Clycleptus elongatus*	1	2	2	Large rivers throughout Mississippi River Basin south and west in major streams of Texas to Rio Grand River		T	Resident
Braken Bat Cave Meshweaver	Cicurina venii	1	3	3	Small eyeless spider, in Karst features in western Bexar County.	LE		Resident
Bracted twistflower	*Streptanthus bracteatus*	2	1	2	endemic, openings in juniper-oak woodlands, rocky slopes			Resident
Buckley Triodia	*Tridens buckleyanus*	2	1	2	Plant.			Resident
Canyon mock-orange	*Philadelphus ernestii*	2	1	2	Outcrops of limestone along canyons.			Resident

Table 4C.20-7 continued

Common Name	Scientific Name	Impact Value	Multiplier Based on Status	Adjusted Impact	Summary of Habitat Preference	Listing Entity		Potential Occurrence in County
						USFWS[1]	TPWD[1]	
Cagle's Map Turtle	*Graptemys caglei*	1	2	2	Guadalupe River System, transition areas between riffles and pools, nests within 30 ft of water's edges	C1	T	Resident
Cascade Caverns Salamander	*Eurycea latitans*	1	2	2	Endemic; subaquatic, springs and caves in Comal Co.		T	Resident
Cave Myotis Bat	*Myotis velifer*	2	1	2	colonial, and cave dwelling; hibernates in limestone caves of Edwards Plateau			Resident
Cokendolpher Cave Harvestman	*Texella cokendolpheri*	1	3	3	Small eyeless harvestman, karst features in north-central Bexar county.	LE		Resident
Comal Blind Salamander	*Eurycea tridentifera*	1	2	2	Endemic; semi-troglobitic; found in springs and waters of caves in Bexar and Comal Co		T	Resident
Comal Nakedwood	*Colubrina stricta*	1	1	1	Shrub.			Resident
Comal Springs Diving Beetle	*Comaldessus stygius*	0	1	0	Outflow at Comal Springs.			Resident
Comal Springs Dryopid Beetle	*Stygoparnus comalensis*	0	3	0	Found in streams.	LE		Resident
Comal Springs Riffle Beetle	*Heterelmis comalensis*	0	3	0	Comal and San Marcos Springs.	LE		Resident
Comal Springs Salamander	*Eurycea sp.8*	2	1	2	Endemic to Comal Springs			Resident
Correll's false dragon-head	*Physostegiacorrellii*	1	1	1	Wet soils including roadside ditches, irrigation channels			Resident
Dark Noseburn	*Tragia nigricans*	0	1	0	Plant.			Resident
Edwards Aquifer Diving Beetle	*Haideoporus texanus*	1	1	1	Known from an artesian well in Hays Co.			Resident
Edwards Plateau Spring Salamander	*Eurycea sp. 7*	2	1	2	Endemic; troglobitic; springs, seeps, cave streams, and creek headwaters			Resident
Edwards Plateau Shiner	*Cyprinella sp.2*	0	1	0	Edwards Plateau portion of Nueces basin.			Resident
Elmendorf's Onion	*Allium elmendorfii*	1	1	1	Endemic; deep sands derived from Queen City and similar Eocene formations			Resident
Ezell's Cave Amphipod	*Stygobromus flagellatus*	0	1	0	Known only from artesian wells			Resident
Flint's net-spinning caddisfly	*Cheumatopsyche flinti*	1	1	1				Resident
Fountain Darter	*Etheostoma fonticola*	1	3	3	Known only from the San Marcos and Comal rivers; springs and spring-fed streams in dense vegetation	LE	E	Resident
Frio Pocket Gopher	*Geomys texensis bakeri*	1	1	1	Associated with nearly level Atoc soil, which is well drained and consists of sandy surface layers with loam extending to as deep as 2m.			Resident

Table 4C.20-7 continued

Common Name	Scientific Name	Impact Value	Multiplier Based on Status	Adjusted Impact	Summary of Habitat Preference	Listing Entity USFWS[1]	TPWD[1]	Potential Occurrence in County
Ghost-faced Bat	*Mormoops megalophylla*	0	1	0	Roosts in caves.			Resident
Glass Mountain coral root	*Hexalectrisnitida*	1	1	1	Mesic woodlands in canyons, lower elevations, under oaks			Resident
Golden-cheeked Warbler	*Dendrpoica chrysoparia*	2	3	6	Juniper-oak woodlands; dependent on mature Ashe juniper (cedar) for nests	LE	E	Nesting/Migrant
Government Cave Spider	*Neoleptoneta microps*	1	3	3	Small, eyeless or essentially eyeless spider; karst features in N and NW Bexar Co.	LE		Resident
Government Canyon Bat Cave Meshweaver	*Cicurina vespera*	0	3	0	Small, eyeless spider, karst features in northwestern Bexar County.	LE		Resident
Gray Wolf	*Canis lupus*	0	3	0	Extirpated.	LE	E	
Ground Beetle #1	*Rhadine exilis*	0	3	0	Eyeless beetle, karst features in northern Bexar County.	LE		Resident
Ground Beetle #2	*Rhadine infernalis*	0	3	0	Small eyeless ground beetle; karst features in northern and western Bexar County.	LE		Resident
Guadalupe Bass	*Micropterus treculi*	2	1	2	Perennial streams of the Edward's plateau region			Resident
Guadalupe Darter	*Percina sciera apristis*	1	1	1	Raceways of medium streams and rivers.			Resident
Headwater catfish	*Ictalurus lupus*	0	1	0	Clear Streams			Historic in Uvalde
Helotes Mold Beetle	*Bastrisodes venyivi*	1	3	3	Small, essentially eyeless mold beetle; karst features in N and NW Bexar Co.	LE		Resident
Henslow's Sparrow	*Ammodramus henslowii*	1	1	1	Weedy fields or cut over areas; bare ground for running and walking			Nesting/Migrant
Hill Country Wild Mercury	*Argythamnia aphoroides*	1	1	1	In grasslands.			Resident
Horseshoe Liptooth	*Daedalochila hippocrepis*	1	1	1	Terrestrial snail.			Resident
Indigo Snake	*Drymarchon corais erebennus*	1	2	2	Grass prairies and sand hills; usually thornbush woodland and mesquie savannah of coastal plain		T	Resident
Interior Least Tern	*Sterna antillarum athalassos*	1	3	3	Inland river sandbars for nesting and shallow water for foraging	LE	E	Nesting/Migrant
Jaguarundi	*Felis yagouaroudi*	1	3	3	South Texas thick brushlands, favors areas near water	LE	E	Resident
Keeled Earless Lizard	*Holbrookia propinqua*	1	1	1	Coastal dunes, Barrier islands and sandy areas			Resident

Table 4C.20-7 continued

Common Name	Scientific Name	Impact Value	Multiplier Based on Status	Adjusted Impact	Summary of Habitat Preference	Listing Entity		Potential Occurrence in County
						USFWS[1]	TPWD[1]	
Long-legged Cave Amphipod	Stygobromus longipes	1	1	1	Found in subterranean streams.			Resident
Madla's Cave Spider	*Cicurina madla*	2	3	2	Small, eyeless or essentially eyeless spider; karst features in N and NW Bexar Co.	LE		Resident
Manfreda Giant-skipper	**Stallingsia maculosus**	0	1	0	Small insect.			Resident
Mexican Hooded Oriole	*Icterus cucullatus cucullatus*	0	1	0	Scrub, mesquite; nests in dense trees.			Resident
Mimic Cavesnail	*Phreatodrobia imitata*	1	1	1	Subaquatic found in two wells penetrating the Edwards Aquifer			Resident
Mountain Plover	*Charadrius montanus*	1	1	1	Non-breeding-shortgrass plains and fields, plowed fields and sandy deserts			Nesting/Migrant
Nueces River Shiner	*Cyprinella sp.2*	0	1	0	Edwards Plateau portion of Nueces basin.			Resident
Nueces Roundnose Minnow	*Dionda serena*	0	1	0	Edwards Plateau portion of Nueces basin.			Resident
Ocelot	*Felis pardalis*	1	3	3	Dense chaparral thickets; mesquite-thorn scrub and live oak mottes; avoids open areas	LE	E	Resident
Parks' Jointweed	*Polygonella parksii*	1	1	1	South Texas Plains; subherbaceous annual in deep loose sands, spring-summer			Resident
Peck's Cave Amphipod	*Stygobromus pecki*	0	3	0	Small, aquatic crustacean; lives underground in Edwards Aquifer	LE	E	Resident
Plains Spotted Skunk	*Spilogale putorius interrupta*	0	1	0	Prefers wooded, brushy areas and tallgrass prairie, fields, prairies, croplands, fence rows, farmyards, forest edges			Resident
Red Wolf	*Canis rufus*	0	3	0	Extirpated.	LE	E	
Reticulate Collared Lizard	*Crotaphytus reticulatus*	1	2	2	Endemic grass prairies of South Texas Plains; usually thornbush, mesquite-blackbrush		T	Resident
Robber Baron Cave Spider	*Cicurina baronia*	1	3	3	Small, eyeless or essentially eyeless spider; karst features in N and NW Bexar Co.	LE		Resident
San Marcos Gambusia	*Gambusia georgei*	0	3	0	Endemic, extinct.	LE	E	
San Marcos Saddle Case Caddisfly	*Protoptila arca*	0	1	0	Known from an artesian well in Hays Co.; 1-2m deep water			Resident
San Marcos Salamander	*Eurycea nana*	0	2	0	Headwaters of San Marcos River, downstream to 1/2 mile past IH-35	LT	T	Resident
Sabinal prairie-clover	*Dalea sabinalis*	2	1	2	Rocky soils.			Resident

Table 4C.20-7 continued

Common Name	Scientific Name	Impact Value	Multiplier Based on Status	Adjusted Impact	Summary of Habitat Preference	Listing Entity		Potential Occurrence in County
						USFWS[1]	TPWD[1]	
Sandhill woolywhite	*Hymenopappuscarrizoanus*	1	1	1	Endemic, deep loose sands of Carrizo, disturbed areas			Resident
Spot-tailed earless Lizard	*Holbrookia lacerata*	1	1	1	Central & Southern Texas; oak-juniper woodlands and mesquite-prickly pear			Resident
Springrun whitehead	*Trichocoronis rivularis*	0	1	0				Resident
Texas amorpha	*Amorpha roemerana*	0	1	0	Plant.			Resident
Texas Blind Salamander	*Eurycea rathbuni*	0	3	0	Troglobitic, water-filled subterranean caverns, along San Marcos Spring Fault	LE	E	Resident
Texas Cave Shrimp	*Palaemonetes antrorum*	1	1	1	Subterranean sluggish streams and pools			Resident
Texas Garter Snake	*Thamnophis sirtalis annectens*	2	1	2	Varied, especially wet areas; bottomlands and pastures			Resident
Texas Grease Bush	*Glossopetalon texense*	2	1	2	Dry limestone ledges.			Resident
Texas Horned Lizard	*Phrynosoma cornutum*	1	2	2	Varied, sparsely vegetated uplands, grass, cactus, brush		T	Resident
Texas Largeseed bittercress	*Cardamine macrocarpa var. texana*	2	1	2	Moist loam soils in pine-oak woodlands.			Resident
Texas Mock-Orange	*Philadelphus texensis*	2	1	2	On limestone bluffs and among boulders on the Edwards Plateau			Resident
Texas Salamander	*Eurycea neotenes*	2	1	2	Endemic, in caves, springs and seeps.		T	Resident
Texas Snowbells	*Styrax platanifolius ssp.texanus*	0	3	0	Limestone bluffs, and cliff faces.	LE	E	Resident
Texas Tortoise	*Gopherus berlandieri*	1	2	2	Open brush with grass understory; open grass and bare ground avoided; occupies shallow depressions at base of bush or cactus, underground burrows, under objects; active March-Nov		T	Resident
Timber Rattlesnake	*Crotalus horridus*	1	2	2	Floodplains, upland pine, deciduous woodlands, riparian zones, abandoned farms, dense ground cover		T	Resident
Texas wild-rice	*Zizania texana*	0	3	0	Perennial, emergent, aquatic grass known from San Marcos River	LE	E	Resident
Tobusch fishhook Cactus	*Sclerocactus brevehamatus var tobuschii*	0	3	0	Endemic, shallow gravelly soil in shortgrass grasslands.	LE	E	Resident

Table 4C.20-7 concluded

Common Name	Scientific Name	Impact Value	Multiplier Based on Status	Adjusted Impact	Summary of Habitat Preference	Listing Entity USFWS[1]	Listing Entity TPWD[1]	Potential Occ in County
Toothless Blindcat	*Trogloglanis pattersoni*	0	2	0	Troglobitic, blind catfish endemic to the San Antonio pool of the Edward's Aquifer		T	Resident
Valdina Farms Sinkhole Salamander	*Eurycea troglodytes*	1	1	1	Isolated, intermittent pools of a subterranean stream; sinkhole found in Medina Co.			Resident
Warnock's coral root	*Hexalectric warnockii*	0	1	0	In oak juniper woodlands.			Resident
White-faced Ibis	*Pelagis chihi*	1	2	2	Prefers freshwater marshes, sloughs, and irrigated rice fields		T	Migrant
White-nosed coati	*Nasua narica*	1	2	2	woodlands, rocky and riparian areas		T	Resident
Whooping Crane	*Grus americana*	0	3	0	Potential migrant	LE	E	Migrant
Widemouth Blindcat	*Satan eurystomus*	0	2	0	troglobitic, blind catfish endemic to the San Antonio pool of the Edward's Aquifer		T	Resident
Wood Stork	*Mycteria americana*	1	2	2	Forages in prairie ponds, ditches, and shallow standing water formerly nested in TX		T	Migrant
Yuma Myotis Bat	*Myotis yumanensis*	0	1	0	Desert regions near open water.			
Zone-tailed Hawk	*Buteo albonotatus*	1	2	2	Arid, open country including deciduous or pine-oak woodland; nests in various habitats and sites		T	Nesting/Migrant

Texas Parks and Wildlife Department (TPWD), Unpublishe0d 2005, March 2005, Data and Map Files of the Wildlife Science Research and Diversity Division maintained by TPWD, Austin, Texas.

* LE/LT=Federally Listed Endangered/Threatened E/SA, T/SA=Federally Listed Endangered/Threatened by Similarity of Appearance

C1=Federal Candidate for Listing DL, PDL=Federally Delisted/Proposed for Delisting NL=not Federally Listed E, T=State Listed Endangered/Threatened

PE, PT=Federally Proposed Endangered/ Threatened Blank = Rare, but no regulatory listing status

The Cibolo Dam #1 site could impact the Guadalupe Bass (*Micropterus treculi*), and two rare plants, Buckley Triodia (*Tridens buckleyanus*) and Texas Mock Orange (*Philadelphus texensis*). Species listed as occurring near the Lower Blanco project area include the Guadalupe Bass (*Micropterus treculi*), and Blanco Blind Salamander (*Eurycea robusta*).

The Government Creek area is known to contain numerous prehistoric sites and a 17th century Spanish colonial trail. Cultural resources protection on public lands in Texas is afforded by the Antiquities Code of Texas (Title 9, Chapter 191, Texas Natural Resource Code of 1977), the National Historic Preservation Act (Pl96-515), and the Archeological and Historic Preservation Act (PL93-291). Based on the review of available records housed at the Texas Archeological Research Laboratory in Austin, sixteen cultural resource sites appear to occur within the proposed project area. Table 4C.20-8 lists archeological sites within a one-mile corridor of the proposed project areas. Considering that the owner or controller of the project will likely be a political subdivision of the State of Texas (i.e. river authority, municipality, county, etc.), they will be required to coordinate with the Texas Historical Commission regarding if the project will affect waters of the United States or wetlands, the project sponsor will also be required to coordinate with the U.S. Army Corps of Engineers regarding impacts to cultural resources. All areas to be disturbed during construction will be first surveyed by qualified professionals for the presence of significant cultural resources. Additional measures to mitigate impacts may be required by the presence of significant cultural deposits that cannot be avoided.

4C.20.4 Engineering and Costing

Preliminary cost estimates for all Type 2 recharge enhancement projects located in the Nueces River Basin were prepared in 1994 by HDR,[17] and preliminary cost estimates for the Type 2 recharge enhancement projects located in the Guadalupe-San Antonio River Basin were prepared in 1998 by HDR.[18,19] These costs were then updated to second quarter 1999 prices for the 2001 Regional Water Plan. The costs presented in Table 4C.20-9 are based on the original costs and have been adjusted to Second Quarter 2002 prices in accordance with TWDB guidance for regional water planning.

---

[17] HDR Engineering, Inc., "Nueces River Basin Edwards Aquifer Recharge Study, Phase IVA," Edwards Underground Water District, May 1994.
[18] HDR, Op. Cit., March 1998.
[19] HDR, "Modification of Principal Spillways at Existing Flood Control Projects for Recharge Enhancement," Trans-Texas Water Program, West Central Study Area, Phase II, Edwards Aquifer Recharge Analyses, San Antonio River Authority, et al., March 1998.

Table 4C.20-8
Previously Recorded Sites within 1-mile Distance from the proposed Edwards Recharge-Type 2 projects.

Reservoir	***Sites***
Indian Creek	41UV371
Lower Frio	41UV249
	41UV251
	41UV258
	41UV259
Lower Sabinal	No sites
Lower Hondo	No sites
Lower Verde	No sites
San Geronimo	41ME7
	41ME8
	41ME108
Cibolo Dam No. 1	No sites
Lower Blanco	41HY11
	41HY51
	41HY104
	41HY139
	41HY229
	41HY230
	41HY231
	41HY232

As seen in Table 4C.20-9, the Type 2 Recharge Program 2A has a total cost of $367,192,000 and a total annual cost of $29,243,000. Under this Program, sustained yield pumpage is enhanced by about 21,577 acft/yr, which results in an estimated unit cost of water of $1,355 per acft.

The Program 2B total cost was computed as $208,813,000 with a total annual cost of $16,113,000. Sustained yield pumpage for Program 2B is 15,980 acft/yr, which results in an estimated unit cost of $1,008 per acft.

Table 4C.20-9 shows that Program 2C appears to be the most efficient program from both a hydrologic and a unit cost standpoint. Its total project cost of $105,012,000 equates to an annual cost of $8,578,000 per year. With a sustained yield increase of 13,451 acft/yr, the resulting annual unit cost of water under Program 2C is $638 per acft. The incremental cost of the additional 2,529 acft/yr provided by Program 2B, as compared to Program 2C, is $2,979 per acft.

Table 4C.20-9.
Summary of Costs for
Edwards Aquifer Recharge Programs — Type 2 Projects (L-18)
Second Quarter 2002 Prices

Item	Program 2A[1]	Program 2B[2]	Program 2C[3]
Capital Costs			
Dams and Reservoirs	$162,668,000	$88,708,000	$54,950,000
Outlet Modifications	33,000	22,000	22,000
Transmission Pipeline	22,387,000	4,219,000	0
Relocations and Others	6,330,000	6,319,000	5,114,000
Total Capital Cost	**$191,405,000**	**$99,246,000**	**$60,064,000**
Engineering, Legal Costs and Contingencies	$65,873,000	$34,525,000	$21,023,000
Environmental & Archaeology Studies and Mitigation	33,644,000	25,248,000	6,681,000
Land Acquisition	34,140,000	25,530,000	6,854,000
Interest During Construction	42,130,000	24,264,000	10,390,000
Total Project Cost	**$367,192,000**	**$208,813,000**	**$105,012,000**
Annual Costs			
Debt Service (6 percent for 30 years)	$2,926,000	$1,141,000	$542,000
Reservoir Debt Service (6 percent for 40 years)	21,726,000	12,834,000	6,483,000
Operation and Maintenance	2,663,000	1,372,000	824,000
Water Rights Mitigation	1,928,000	766,000	729,000
Total Annual Cost	**$29,243,000**	**$16,113,000**	**$8,578,000**
Available Project Yield (acft/yr)	**21,577**	**15,980**	**13,451**
Annual Cost of Water ($ per acft) Raw Water in Aquifer[4]	**$1,355**	**$1,008**	**$638**
Annual Cost of Water ($ per 1,000 gallons)	**$4.16**	**$3.09**	**$1.96**

[1] Program 2A includes Indian Creek, Lower Frio, Lower Sabinal, Lower Hondo, Lower Verde, Lower Blanco, Cibolo Dam No. 1, San Geronimo, Northern Bexar/Medina County Projects, Dry Comal, and Salado Creek FRS outlet modifications.

[2] Program 2B includes Lower Frio, Lower Sabinal, Lower Hondo, Lower Verde, Lower Blanco, Cibolo Dam No. 1, San Geronimo, and Salado Creek FRS outlet modifications.

[3] Program 2C includes Lower Frio, Lower Sabinal, Lower Hondo, Lower Verde, Cibolo Dam No. 1, and Salado Creek FRS outlet modifications.

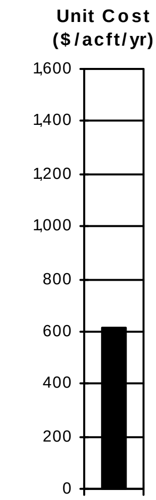
[4] Reported Annual Cost of Water is for additional water supply in the Edwards Aquifer.

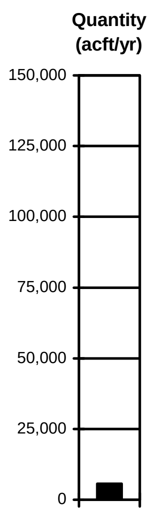
4C.20.5 Implementation Issues

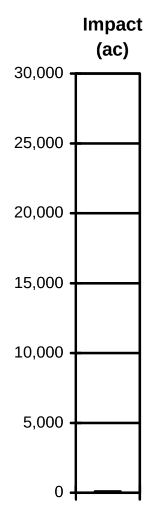
An institutional arrangement may be needed to implement this project including financing on a regional basis.

- Necessary permits could include:
  - TCEQ Water Right and Storage permits;
  - USACE Sections 10 and 404 dredge and fill permits for the reservoir and pipelines;
  - TWDB Sand, Gravel, and Marl Removal permits; and
  - GLO Easement for use of state-owned land.
  - Edwards Aquifer Authority aquifer storage and recharge recovery permits.
- Permitting, at a minimum, will require these studies:
  - Assessment of changes in instream flow and freshwater inflows to bays and estuaries;
  - Habitat mitigation plan;
  - Environmental studies;
  - Cultural resource studies; and
  - Study of impact on karst geology organisms.
- Land and/or easements must be acquired through either negotiations or condemnation.
- Relocations and crossings:
  - Highways and railroad; and
  - Other utilities.

2006 South Central Texas Regional Water Plan
Water Management Strategy Summary Sheet







***Name: Brackish Groundwater Desalination - Wilcox Aquifer* (WW White Tank Delivery, 5 MGD)**

Description: Strategy involves the development of a well field in the brackish portion of the Wilcox Aquifer in Bexar County. Facilities include a well field with production capacity of 6,291 acft/yr (15 wells at 300 gpm, including 2 back-up wells), brackish groundwater desalination plant with finished water capacity of 2,516 acft/yr, deep well injection of desalination concentrate, finished water tank, finished water pump station and 14-mile 20-inch transmission pipeline to transport blended finished water to the WW White tank. Treated water transmission system improvements for integration of the additional supply are not included because the finished water is delivered into the existing distribution system. Strategy has been sized for delivery on a uniform basis.

***Decade Needed*:** 2000 – 2010

Cost, Quantity of Water, and Land Impacted

Unit Cost of Water:	**612**	**$/acft/yr**	**Treated Water Delivered**
Quantity of Water:	**5,662**	**acft/yr**	**Reliability = Firm**
Land Impacted:	**102**	**acres**	

Additional Considerations per Regional Water Planning Guidelines

Environmental Factors:

Permits required for deep well injection of desalination concentrate.

Impacts on Water Resources:

Long-term reductions in aquifer levels.

Impacts on Agricultural & Natural Resources:

Minimal, if any.

Other Relevant Factors per SCTRWPG:

Beneficial use of groundwater now unused. Currently no groundwater conservation district for the Carrizo-Wilcox Aquifer in Bexar County.

Comparison of Strategies to Meet Needs:

No conflicts with other recommended water management strategies.

Interbasin Transfer Issues:

None anticipated.

Third-Party Impacts of Voluntary Transfers:

None anticipated.

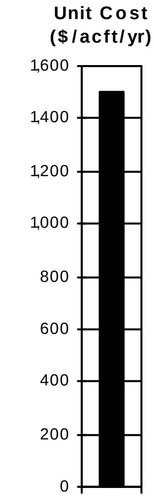
Regional Efficiency:

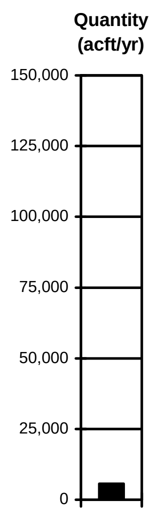
Beneficial use of groundwater currently unused. Proximate to existing transmission system for Twin Oaks WTP into San Antonio.

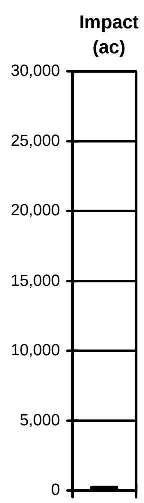
Water Quality Considerations:

Strategy assumes desalination of 50% of brackish groundwater with 1,200 mg/l TDS required to decrease dissolved solids below regulatory levels and allow blending with other distribution system water sources without adverse water quality impacts. Desalination process recovery of 80% with 20% rejected concentrate to deep well injection.

2006 South Central Texas Regional Water Plan
Water Management Strategy Summary Sheet







***Name: Brackish Groundwater Desalination - Wilcox Aquifer* (WW White Tank Delivery, 20 MGD Peak, 5 MGD Yearly Average)**

Description: Strategy involves the development of a well field in the brackish portion of the Wilcox Aquifer in Bexar County. Facilities include a well field with production capacity of 25,163 acft/yr (56 wells at 300 gpm, including 4 back-up wells), brackish groundwater desalination plant with finished water capacity of 10,065 acft/yr, deep well injection of desalination concentrate, finished water tank, finished water pump station and 14-mile 33-inch transmission pipeline to transport blended finished water to the WW White tank. Treated water transmission system improvements for integration of the additional supply are not included because the finished water is delivered into the existing distribution system. Strategy has been sized for delivery on a seasonal basis with 20 MGD peak capacity and 5 MGD yearly average.

***Decade Needed*:** 2000 – 2010

Cost, Quantity of Water, and Land Impacted

Unit Cost of Water:	**1,502**	**$/acft/yr**	**Treated Water Delivered**
Quantity of Water:	**5,662**	**acft/yr**	**Reliability = Firm**
Land Impacted:	**242**	**acres**	

Additional Considerations per Regional Water Planning Guidelines

Environmental Factors:
Permits required for deep well injection of desalination concentrate.

Impacts on Water Resources:
Long-term reductions in aquifer levels.

Impacts on Agricultural & Natural Resources:
Minimal, if any.

Other Relevant Factors per SCTRWPG:
Beneficial use of groundwater now unused. Currently no groundwater conservation district for the Carrizo-Wilcox Aquifer in Bexar County.

Comparison of Strategies to Meet Needs:
No conflicts with other recommended water management strategies.

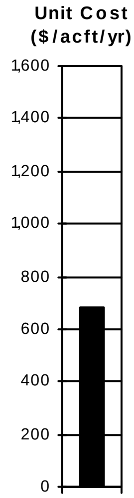
Interbasin Transfer Issues:
None anticipated.

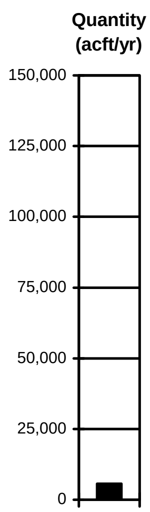
Third-Party Impacts of Voluntary Transfers:
None anticipated.

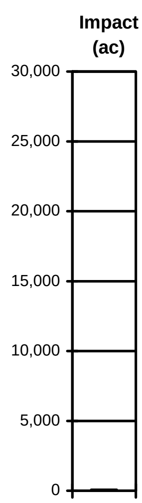
Regional Efficiency:
Beneficial use of groundwater currently unused. Proximate to existing transmission system for Twin Oaks WTP into San Antonio.

Water Quality Considerations:
Strategy assumes desalination of 50% of brackish groundwater with 1,200 mg/l TDS required to decrease dissolved solids below regulatory levels and allow blending with other distribution system water sources without adverse water quality impacts. Desalination process recovery of 80% with 20% rejected concentrate to deep well injection.

2006 South Central Texas Regional Water Plan
Water Management Strategy Summary Sheet







***Name: Brackish Groundwater Desalination - Wilcox Aquifer* (Twin Oaks WTP Delivery, 5 MGD)**

Description: Strategy involves the development of a well field in the brackish portion of the Wilcox Aquifer in Bexar County. Facilities include a well field with production capacity of 6,291 acft/yr (15 wells at 300 gpm, including 2 back-up wells), brackish groundwater desalination plant with finished water capacity of 2,516 acft/yr, deep well injection of desalination concentrate, finished water tank, finished water pump station and 8-mile 20-inch transmission pipeline to transport blended finished water to the clearwell at the Twin Oaks WTP, and treated water transmission system improvements for integration of the additional supply. Strategy has been sized for delivery on a uniform basis.

***Decade Needed*:** 2000 – 2010

Cost, Quantity of Water, and Land Impacted

Unit Cost of Water:	**685**	**$/acft/yr**	**Treated Water Delivered**
Quantity of Water:	**5,662**	**acft/yr**	**Reliability = Firm**
Land Impacted:	**79**	**acres**	

Additional Considerations per Regional Water Planning Guidelines

Environmental Factors:

Permits required for deep well injection of desalination concentrate.

Impacts on Water Resources:

Long-term reductions in aquifer levels.

Impacts on Agricultural & Natural Resources:

Minimal, if any.

Other Relevant Factors per SCTRWPG:

Beneficial use of groundwater now unused. Currently no groundwater conservation district for the Carrizo-Wilcox Aquifer in Bexar County.

Comparison of Strategies to Meet Needs:

No conflicts with other recommended water management strategies.

Interbasin Transfer Issues:

None anticipated.

Third-Party Impacts of Voluntary Transfers:

None anticipated.

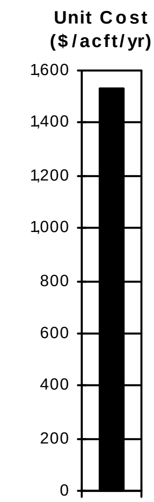
Regional Efficiency:

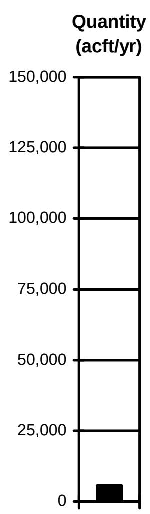
Beneficial use of groundwater currently unused. Proximate to existing transmission system for Twin Oaks WTP into San Antonio.

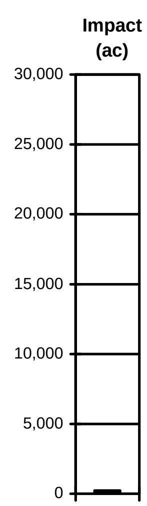
Water Quality Considerations:

Strategy assumes desalination of 50% of brackish groundwater with 1,200 mg/l TDS required to decrease dissolved solids below regulatory levels and allow blending with other distribution system water sources without adverse water quality impacts. Desalination process recovery of 80% with 20% rejected concentrate to deep well injection.

2006 South Central Texas Regional Water Plan
Water Management Strategy Summary Sheet







Name: Brackish Groundwater Desalination - Wilcox Aquifer **(Twin Oaks WTP Delivery, 20 MGD Peak, 5 MGD Yearly Average)**

Description: Strategy involves the development of a well field in the brackish portion of the Wilcox Aquifer in Bexar County. Facilities include a well field with production capacity of 25,163 acft/yr (56 wells at 300 gpm, including 4 back-up wells), brackish groundwater desalination plant with finished water capacity of 10,065 acft/yr, deep well injection of desalination concentrate, finished water tank, finished water pump station and 8-mile 33-inch transmission pipeline to transport blended finished water to the clearwell at the Twin Oaks WTP, and treated water transmission system improvements for integration of the additional supply. Strategy has been sized for delivery on a seasonal basis with 20 MGD peak capacity and 5 MGD yearly average.

***Decade Needed*:** 2000 – 2010

Cost, Quantity of Water, and Land Impacted

Unit Cost of Water:	**1,533**	**$/acft/yr**	**Treated Water Delivered**
Quantity of Water:	**5,662**	**acft/yr**	**Reliability = Firm**
Land Impacted:	**220**	**acres**	

Additional Considerations per Regional Water Planning Guidelines

Environmental Factors:
Permits required for deep well injection of desalination concentrate.

Impacts on Water Resources:
Long-term reductions in aquifer levels.

Impacts on Agricultural & Natural Resources:
Minimal, if any.

Other Relevant Factors per SCTRWPG:
Beneficial use of groundwater now unused. Currently no groundwater conservation district for the Carrizo-Wilcox Aquifer in Bexar County.

Comparison of Strategies to Meet Needs:
No conflicts with other recommended water management strategies.

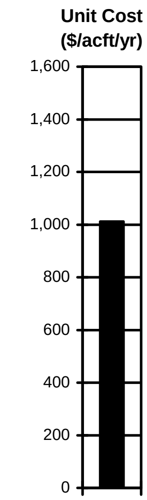
Interbasin Transfer Issues:
None anticipated.

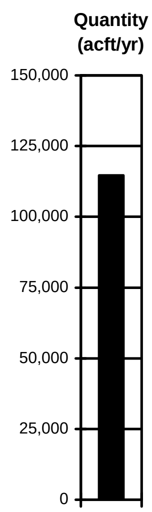
Third-Party Impacts of Voluntary Transfers:
None anticipated.

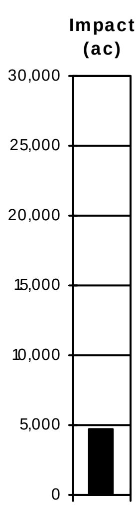
Regional Efficiency:
Beneficial use of groundwater currently unused. Proximate to existing transmission system for Twin Oaks WTP into San Antonio.

Water Quality Considerations:
Strategy assumes desalination of 50% of brackish groundwater with 1,200 mg/l TDS required to decrease dissolved solids below regulatory levels and allow blending with other distribution system water sources without adverse water quality impacts. Desalination process recovery of 80% with 20% rejected concentrate to deep well injection.

2006 South Central Texas Regional Water Plan
Water Management Strategy Summary Sheet







Name: Brackish Groundwater Desalination – Gulf Coast Aquifer

Description: Facilities include all facilities for LGWSP – In-basin Use with 91.5-mile 84-inch transmission pipeline from the off-channel storage to a terminal storage site in southern Bexar County (TS-6). Additional facilities include a brackish well field with production capacity of 11,291 acft/yr (8 wells at 1,000 gpm, including 1 back-up well), brackish groundwater desalination plant with finished water capacity of 4,516 acft/yr, and 16-mile 12-inch desalination concentrate pipeline discharging to Hynes Bay. Groundwater use for strategy is variable with average desalted brackish water contribution of 4,814 acft/yr. Strategy has been sized for delivery on a uniform basis. It is assumed that the LGWSP is not an interbasin transfer in this analysis.

***Decade Needed*:** Not recommended to meet projected needs.

Cost, Quantity of Water, and Land Impacted

Unit Cost of Water:	**$1,012**	**$/acft/yr**	**Treated Water Delivered**
Quantity of Water:	**114,647**	**acft/yr**	**Reliability = Firm**
Land Impacted:	**4,717**	**acres**	

Additional Considerations per Regional Water Planning Guidelines

Environmental Factors:
Wintering population of endangered Whooping Cranes at the Aransas National Wildlife Refuge located adjacent to lower San Antonio Bay. Pipeline could traverse Attwater Prairie Chicken habitat. Surface water diversions from an Ecologically Significant River & Stream Segment per TPWD. Desalination concentrate with total dissolved solids of 6,000 mg/l discharged to Hynes Bay may impact ambient salinity of Bay that varies in the range of 3,000 to 26,000 mg/l.

Impacts on Water Resources:
Some reductions in freshwater inflows to the Guadalupe Estuary associated with greater utilization of existing water rights and new appropriation of streamflow. Modest long-term reductions in aquifer levels with more significant transient reductions during severe drought.

Impacts on Agricultural & Natural Resources:
Minimal, if any.

Other Relevant Factors per SCTRWPG:
Encourages beneficial use of available rights. Protects instream flows and recreational opportunities through lower basin diversion. Conformance with groundwater conservation district rules. Interactions and cumulative effects of Region L and Region N water management strategies including potential exports of groundwater from Refugio County.

Comparison of Strategies to Meet Needs:
No conflicts with other recommended water management strategies. Unit cost of delivered water decreased with additional yield from desalted groundwater. Unit cost of brackish groundwater component is $796/acft/yr. Decrease in overall unit cost would be greater if additional groundwater did not require desalination.

Interbasin Transfer Issues:
TWDB and/or Legislative clarification of the interbasin transfer status of this project is necessary.

Third-Party Impacts of Voluntary Transfers:
None Anticipated.

Regional Efficiency:
Shared pipeline alignment with other recommended water management strategies. Potential for shared water treatment and balancing storage facilities in Bexar County.

Water Quality Considerations:
Average total dissolved solids (TDS) for brackish groundwater well field assumed to be 1,200 mg/l. After desalination of half the brackish groundwater, water quality of the blended groundwater from brackish well field is similar to quality of other Gulf Coast aquifer groundwater (TDS of 800 mg/l). Bromides in groundwater mixed with surface water may increase treatment costs in order to meet disinfection by-product requirements in the treated-chlorinated finished water.

(This page intentionally left blank.)

4C.21 Brackish Groundwater Desalination

In the Texas Water Development Board's February 2003 report[1], the availability of brackish water in the Wilcox and Gulf Coast Aquifers in Region L is shown to range from "moderate" to "high" while source water production costs range from "low" to "high." A study completed in July 2004[2] to evaluate the potential for a brackish groundwater source from the Wilcox Aquifer further defined the water quality and indicated that slightly brackish groundwater was available from the Wilcox Aquifer in Bexar County.

A report prepared in September 2003[3] for the Lower Guadalupe Water Supply Project (LGWSP) evaluated the quantity and quality of water from the Gulf Coast Aquifer and concluded that ground water is available in Goliad, Refugio, and Victoria Counties as a water supply to provide firm yield for the proposed LGWSP. Three potential well field areas in the Gulf Coast Aquifer were outlined for the LGWSP and groundwater from these well field areas is included as part of the LGWSP strategy evaluated in the 2006 Regional Water Plan (Section 4C.7). The water from these three well field areas is considered to be fresh and, therefore, desalination was not included in the strategy to utilize the groundwater source.

Based on the findings of previous studies, the following two strategies were developed for the use of brackish groundwater:

- Production from the Wilcox Aquifer in Bexar County, treatment, and integration into water supply system in Bexar County; and
- Production from the Gulf Coast Aquifer in Refugio County and treatment as necessary for use as an additional water source for the Lower Guadalupe Supply Project.

4C.21.1 Wilcox Aquifer

4C.21.1.1 Description of Water Management Strategy

Two strategies were developed for providing a water supply from brackish groundwater in the Wilcox Aquifer in Bexar County. Two delivery methods to supply the same yearly quantity of water were evaluated for each strategy: 1) size facilities to deliver finished water at a

---

[1] LBG-Guyton Associates, "Brackish Groundwater Manual for Texas Regional Water Planning Groups," prepared for the Texas Water Development Board, February 2003.
[2] HDR Engineering, Inc., "Water Quality Characteristics of the Wilcox Aquifer in the Vicinity of San Antonio, TX," prepared for San Antonio Water System, July 2004.
[3] LBG-Guyton Associates, "Lower Guadalupe Water Supply Project Groundwater Availability Study", Prepared for SARA, SAWS, and GBRA, September 2003.

uniform rate all year long; and 2) up-size facilities to deliver water at a higher rate, but only during a three month peak demand period. The strategies include a well field located in the outcrop region of the Wilcox Aquifer in south Bexar County with 300 gpm, 750 feet deep wells pumping Wilcox Aquifer water with a total dissolved solids (TDS) concentration of 1,200 mg/L. Desalination facilities are located adjacent to the well field and are sized to treat half the brackish water to produce a finished blended water supply that meets all potable water regulatory requirements including concentrations of the dissolved constituents TDS, chloride, and sulfate.

The two strategies differ in the finished water delivery location. The two delivery locations evaluated were: 1) delivery directly into the SAWS distribution system at the WW White tank in southeast San Antonio as shown in Figure 4C.21.1-1; and 2) delivery to the Twin Oaks WTP to be mixed with other water sources and delivered either to east or west San Antonio as shown in Figure 4C.21.1-2. The location of the well field was selected to minimize the finished water transmission distance and utilize a more productive area of the Wilcox Aquifer.

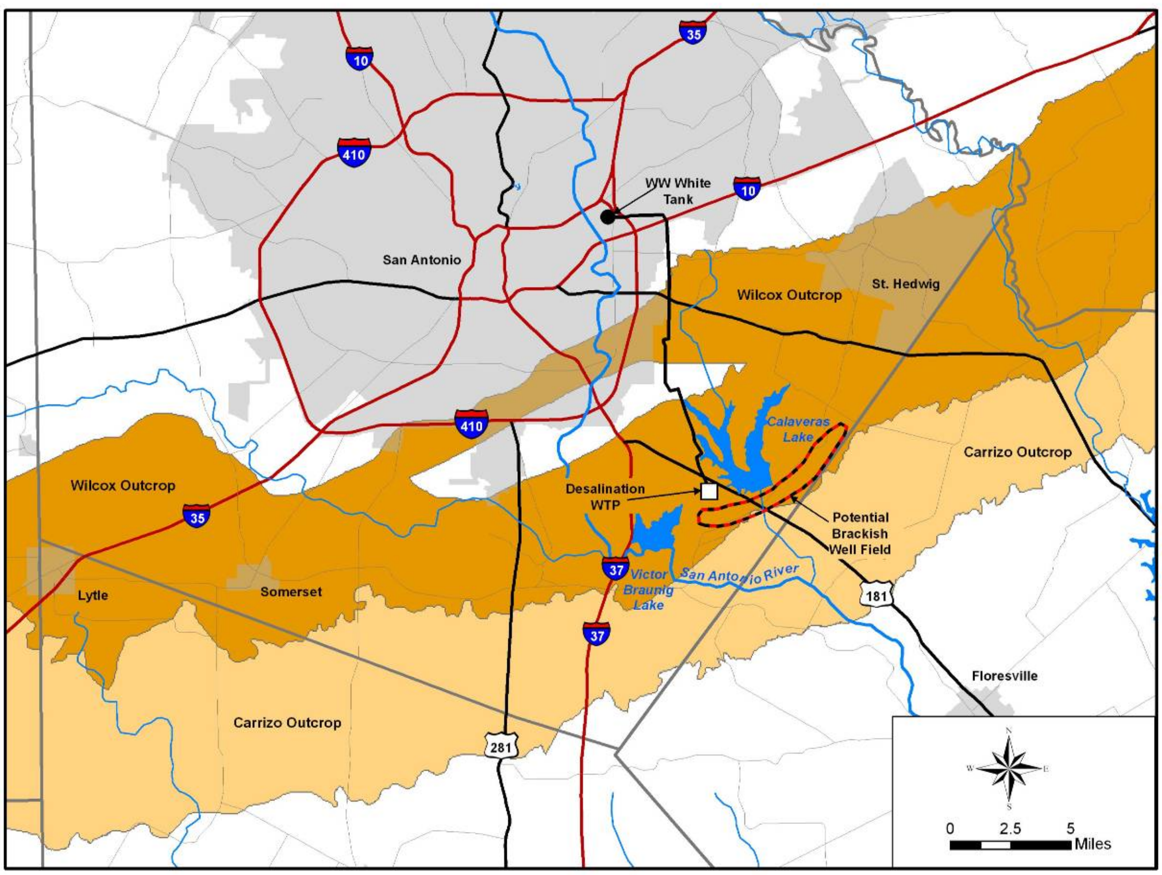


Figure 4C.21.1-1. Brackish Groundwater Desalination – Wilcox Aquifer (WW White Tank Delivery)

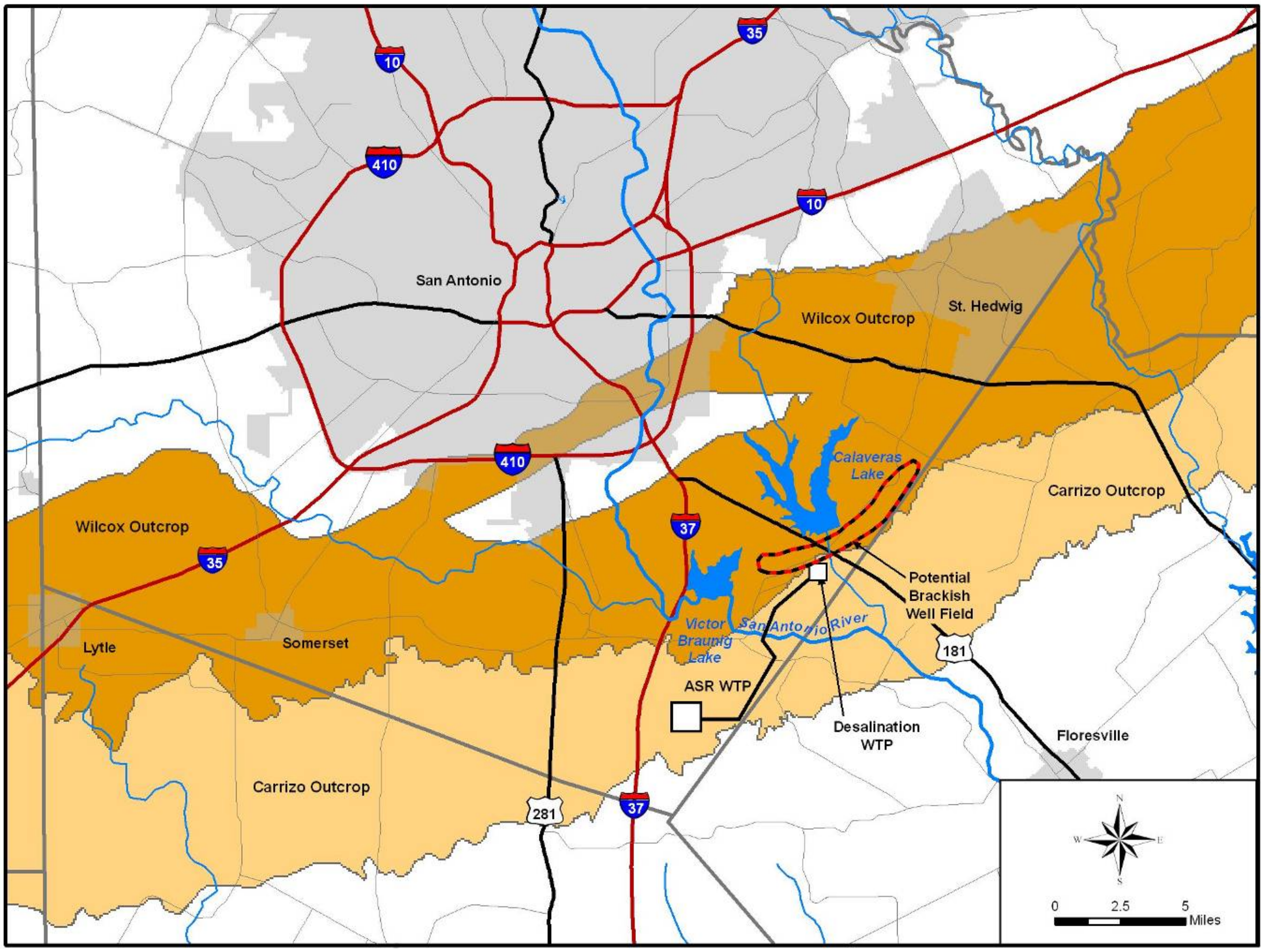


Figure 4C.21.1-2. Brackish Groundwater Desalination – Wilcox Aquifer (Twin Oaks WTP Delivery)

4C.21.1.2 Available Yield

The available water for this brackish water strategy was limited to wells located in the outcrop area of the Wilcox aquifer in Bexar County. Other potential areas to obtain brackish water in the Carrizo-Wilcox aquifer were not considered due to potential conflicts with other projects and limitations of groundwater districts in other areas of the Carrizo-Wilcox aquifer. There currently is not a groundwater conservation district for the Carrizo-Wilcox aquifer in Bexar County. The Carrizo and Wilcox sands are sometimes difficult to distinguish from each other, and they are often hydraulically interconnected, and therefore the term “Carrizo-Wilcox aquifer” is often used. In areas where both the Carrizo and Wilcox aquifers are present, the “Carrizo-Wilcox aquifer” is one of the most extensive and productive aquifers in Texas.

However, for this brackish groundwater strategy the available water is limited to water from the Wilcox aquifer sands in the outcrop area of the Wilcox aquifer in Bexar County. The outcrop area is not overlain by the Carrizo aquifer, and therefore the water quality and productivity of wells in the outcrop area are influenced only by the characteristics of the Wilcox aquifer and would not have the potential to deplete the Carrizo. The productivity of the Wilcox aquifer in this outcrop area is expected to be considerably less productive than wells located in the Carrizo-Wilcox aquifer.

Productivity data for the Wilcox aquifer in the outcrop area in Bexar County is limited, but high capacity wells are expected to yield 200 to 400 gpm; 300 gpm capacity wells were selected for this strategy. The total available water from this area of the Wilcox Aquifer will be limited by drawdown and available water-bearing zones. Groundwater modeling was conducted to develop estimates on well spacing, productivity, well depth to water bearing zones, drawdown, and static water level. The well field modeled consisted of 15 wells (including 2 stand-by) at 300 gpm [6,291 acft/yr (5.6 MGD)] spaced about 4,000 ft apart located in the outcrop area near the transition to the confined section of the Wilcox aquifer. As shown in Figure 4C.21.1-3, modeling this pumpage rate resulted in drawdown around the well field of about 75 to 100 ft, with drawdowns exceeding 125 ft at the pumping wells. It should be noted that the well field modeling did not include potential effects on the adjacent Calaveras and Braunig Lakes.

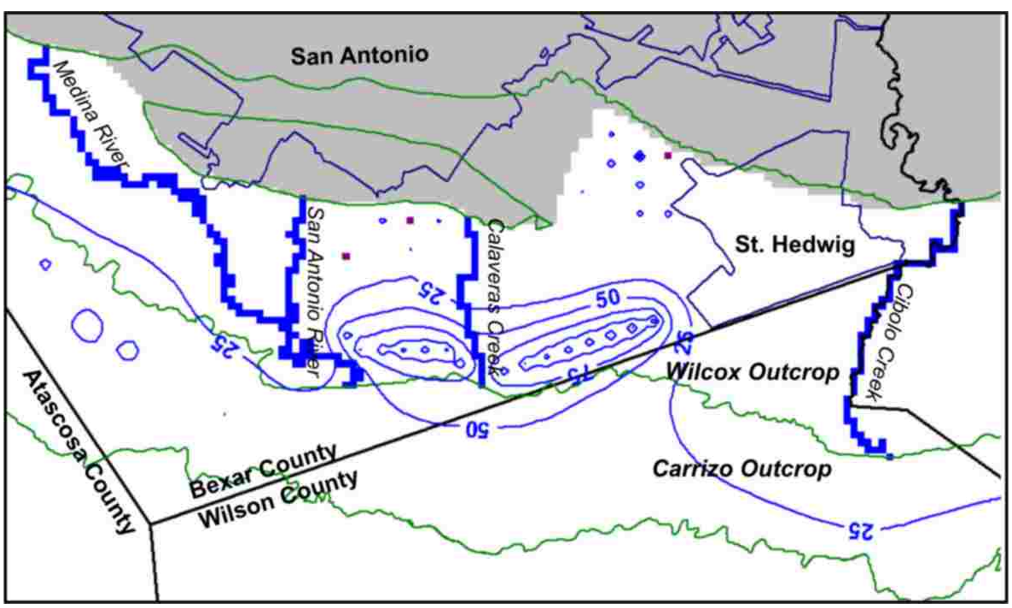


Figure 4C.21.1-3. Wilcox Aquifer Groundwater Model Results

The yearly production from the well field is the same for the peaking strategies as for the uniform delivery strategies, but the larger number of wells are operated for only three months per year for the peaking strategies. Groundwater modeling was not performed for the peaking strategies that consist of 54 wells (including 4 stand-by) at 300 gpm [25,163 acft/yr (22.5 MGD)]. It is assumed that the wells for the peaking strategies will have the same spacing at about 4,000 ft apart and will be located in the same portion of the Wilcox aquifer.

4C.21.1.3 Environmental Issues

Brackish Groundwater Desalination-Wilcox Aquifer involves the development of a well field in the brackish portion of the Wilcox Aquifer in Bexar County, desalination plant, pump station and 14 mile transmission pipeline to the distribution station.

Plant and animal species listed by USFWS and TPWD that may be within the vicinity of this water management strategy are listed in Table 4C.21.1-1. The Wildlife Science Research and Diversity Maps, maintained by TPWD indicate species of rare plants in the vicinity of the project including Parks Jointweed (*Polygonella parksii*), Sandhill Woolywhite (*Hymenopappus carrizoanus*), Bracted Twistflower (*Notophtalmus meridionalis),* and Elmendorf's Onion (*Allium elmendorfi*).

Only the federally listed endangered black-capped vireo (*Vireo atricapillus*) may have habitat within the study area. The black-capped vireo nests in dense underbrush in semi-open woodlands having distinct upper and lower stories. Along the pipeline route, several species listed as threatened by the state may possibly be affected. These include the Cagle's Map Turtle (Graptemys caglei), Indigo Snake (*Drymarchon corais erebennus),* Texas Horned Lizard (*Phrynosoma cornutum),* Texas Tortoise (*Gopherus berlandieri),* and Black-spotted Newt (*Notophthalmus meridionalis),*

Habitat studies and surveys for protected species, and for cultural resources may need to be conducted at the proposed well sites and along any pipeline routes. Potential wetland impacts, which are limited to pipeline stream crossings, can be minimized by right-of-way selection and appropriate construction methods, including erosion controls and revegetation procedures. Compensation for net losses of wetlands would be required where impacts are unavoidable.

Table 4C.21.1-1.
Important Species Having Habitat or Known to Occur in
Counties Potentially Affected by Brackish Groundwater Desalination-Wilcox Aquifer

Common Name	*Scientific Name*	*Impact Value*	*Multiplier Based on Status*	*Adjusted Impact*	*Summary of Habitat Preference*	*Listing Entity*		*Potential Occurrence in County*
						USFWS[1]	*TPWD[1]*	
American Peregrine Falcon	*Falco peregrinus anatum*	0	3	0	Open country; cliffs	DL	E	Nesting/Migrant
Arctic Peregrine Falcon	*Falco peregrinus tundrius*	0	2	0	Open country; cliffs	DL	T	Nesting/Migrant
Big Red Sage	*Salvia penstemonoides*	1	1	1	Endemic; Creekbeds and seepage slopes of limestone canyons			Resident
Black Bear	*Ursus amricanus*	0	2	0	Bottomland hardwoods.	T/SA; NL	T	
Black-capped Vireo	*Vireo atricapillus*	1	3	3	Semi-open broad-leaved shrublands	LE	E	Nesting/Migrant
Black-spotted Newt	*Notophthalmus meridionalis*	2	2	4	Wet or temporally wet arroyos, canals, ditches, shallow depressions; aestivates underground during dry periods		T	Resident
Bracted Twistflower	Streptanthus bracteatus	2	1	2	Endemic; Shallow clay soils over limestone; rocky slopes			Resident
Braken Bat Cave Meshweaver	*Cicurina venii*	0	3	0	Small eyeless spider, in Karst features in western Bexar County.	LE		Resident
Cagle's Map Turtle	*Graptemys caglei*	0	2	0	Endemic, Guadalupe River System.	C1	T	Resident
Cave Myotis Bat	*Myotis velifer*	0	1	0	Colonial & cave dwelling; hibernates in limestone caves of Edwards Plateau			Resident
Cokendolpher Cave Harvestman	*Texella cokendolpheri*	0	3	0	Small eyeless harvestman, karst features in north-central Bexar county.	LE		Resident
Comal Blind Salamander	*Eurycea tridentifera*	0	2	0	Endemic; Semi-troglobitic; Springs and waters of caves		T	Resident
Correll's False Dragon-Head	*Physostegia correllii*	1	1	1	Wet soils			Resident

Table 4C.21.1-1 (Continued)

Edwards Plateau Spring Salamander	*Eurycea sp. 7*	0	1	0	Troglobitic; Edwards Plateau			Resident
Elmendorf's Onion	*Allium elmendorfii*	2	1	2	Endemic; deep sands derived from Queen City and similar Eocene formations			Resident
Golden-Cheeked Warbler	*Dendroica chrysoparia*	0	3	0	Woodlands with oaks and old juniper	LE	E	Nesting/Migrant
Government Canyon Bat Cave Meshweaver	*Cicurina vespera*	0	3	0	Small, eyeless spider, karst features in northwestern Bexar County.	LE		Resident
Government Canyon Bat Cave Spider	Neoleptoneta microps	0	3	0	Small eyeless spider, karst features in northwestern Bexar County.	LE		Resident
Ground Beetle #1	*Rhadine exilis*	0	3	0	Eyeless beetle, karst features in northern Bexar County.	LE		Resident
Ground Beetle #2	*Rhadine infernalis*	0	3	0	Small eyeless ground beetle; karst features in northern and western Bexar County.	LE		Resident
Guadalupe Bass	*Micropterus treculi*	0	1	0	Streams of eastern Edwards Plateau			Resident
Helotes Mold Beetle	*Batrisodes venyivi*	0	3	0	Small eyeless modle beetle; karst features in northwestern Bexar County.	LE		Resident
Henslow's Sparrow	*Ammodramus henslowii*	1	1	1	Weedy fields or cut over areas; bare ground for running and walking			Nesting/Migrant
Indigo Snake	*Drymarchon corais*	1	2	2	Woodlands of south Texas.		T	Resident
Jaguarundi	Felis yagouaroundi	0	3	0	South Texas thick brushlands, favors areas near water	LE	E	Resident
Keeled Earless Lizard	Holbrookia propinqua	1	1	1	Sandy areas.			Resident
Manfreda Giant-skipper	*Stallingsia maculosus*	1	1	1	Small insect.			Resident

Table 4C.21.1-1 (Continued)

Madla Cave Meshweaver	*Cicurina madla*	0	3	0	Small eyeless spider, karst features in northern Bexar County.	LE		Resident
Mimic Cavesnail	*Phreatodrobia imitata*	0	1	0	Subaquatic; wells in Edwards Aquifer			Resident
Mountain Plover	*Charadrius montanus*	0	1	0	Shortgrass plains and fields, sandy deserts, plowed fields			Nesting/Migrant
Nueces Crayfish	Procambarus nueces	0	1	0	Known only from one tributary to the Nueces River.			Resident
Ocelot	*Leopardus pardalis*	0	3	0	Dense chaparral thickets.	LE	E	Resident
Parks' Jointweed	*Polygonella parksii*	1	1	1	South Texas Plains; subherbaceous annual in deep loose sands, spring-summer			Resident
Plains Spotted Skunk	Spilogale putorius interrupta	1	1	1	Catholic; Wooded, brushy areas and tallgrass prairies			Resident
Robber Baron Cave Meshweaver	Cicurina baronia	0	3	0	Small, eyeless spider, karst features in north-central Bexar County.	LE		Resident
Sandhill Woolywhite	Hymenopappus carrizoanus	0	1	0	Endemic; Open areas in deep sands derived from Carrizo and similar Eocene formations			Resident
Spot-tailed Earless Lizard	*Holbrookia lacerata*	1	1	1	Oak-juniper woodlands and mesquite-prickly pear			Resident
Texas Garter Snake	*Thamnophis sirtalis annectens*	1	1	1	Varied, especially wet areas; bottomlands and pastures			Resident
Texas Horned Lizard	*Phrynosoma cornutum*	1	2	2	Varied, sparsely vegetated uplands		T	Resident
Texas Salamander	*Eurycea neotenes*	0	1	0	Endemic, in springs, seeps and caves.			Resident

Table 4C.21.1-1 (Concluded)

Texas Tortoise	*Gopherus berlandieri*	1	2	2	Open brush with grass understory; open grass and bare ground avoided; occupies shallow depressions at base of bush or cactus, underground burrows, under objects; active March-Nov		T	Resident
Toothless Blindcat	*Trogloglanis pattersoni*	0	2	0	Troglobitic; San Antonio pool of the Edwards Aquifer		T	Resident
White-faced Ibis	*Plegadis chihi*	0	2	0	Varied, prefers freshwater marshes, sloughs and irrigated rice fields; Nests in low trees		T	Nesting/Migrant
Widemouth Blindcat	*Satan eurystomus*	0	2	0	Troglobitic; San Antonio pool of Edwards Aquifer		T	Resident
Whooping Crane	*Grus americana*	0	3	0	Potential migrant	LE	E	Migrant
Wood Stork	*Buteo americana*	0	2	0	Prairie ponds, flooded pastures or fields; shallow standing water		T	Nesting/Migrant
Zone-tailed Hawk	*Buteo albonotatus*	0	2	0	Arid, open country including deciduous or pine-oak woodland; nests in various habitats and sites		T	Nesting/Migrant

[1] Texas Parks and Wildlife Department (TPWD), Unpublished 2005, March 2005, Data and Map Files of the Wildlife Science Research and Diversity Division maintained by TPWD, Austin, Texas.

- LE/LT=Federally Listed Endangered/Threatened
- E/SA, T/SA=Federally Listed Endangered/Threatened by Similarity of Appearance
- C1=Federal Candidate for Listing
- DL, PDL=Federally Delisted/Proposed for Delisting
- NL=not Federally Listed
- E, T=State Listed Endangered/Threatened
- PE, PT=Federally Proposed Endangered/ Threatened
- Blank = Rare, but no regulatory listing status

Cultural resources protection on public lands in Texas is afforded by the Antiquities Code of Texas (Title 9, Chapter 191, Texas Natural Resource Code of 1977), the National Historic Preservation Act (Pl96-515), and the Archeological and Historic Preservation Act (PL93-291). Based on the review of available records housed at the Texas Archeological Research Laboratory in Austin, six cultural resource sites appear to occur within the proposed project area. Table 4C.21.1-2 lists archeological sites within a one-mile corridor of the project area

Table 4C.21.1-2.
Previously Recorded Sites within 1-mile Corridor of the Proposed Brackish Groundwater Desalination Wilcox Aquifer Project Area

Sites	BX1460
	BX839
	BX771
	BX772
	BX782
	BX784

4C.21.1.4 Engineering and Costing

The engineering and costing analysis includes all facilities required for well production from the Wilcox Aquifer in Bexar County, treatment, and integration into the water supply system in Bexar County. The well field will require wells and a collector pipeline. Desalination water treatment will be provided at a plant located adjacent to the well field. The Wilcox aquifer water total dissolved solids (TDS) concentration is estimated to average 1,200 mg/L. The required secondary Maximum Contaminant Level (MCL) for TDS is 1,000 mg/L. The estimates assume that half the raw water from the well field is sent to the desalination plant to remove dissolved solids. The desalination plant recovery rate is 80% meaning that 80% of the water entering the desalination plant passes through as purified water and 20% of the water remains as concentrated brine containing the constituents removed from the purified water. The concentrate from the desalination process is disposed of by injection into a deep well. The desalinated water is blended back with the untreated brackish water to produce a blended finished water that is 90% of the quantity of raw water produced from the well field. (50% not desalted + 50% desalted * 80% recovery = 90%). The blended finished water TDS concentration is about 670 mg/L. Pretreatment prior to the desalination process includes cartridge filtration with no additional pretreatment included for removal of particulates such as iron or manganese.

The facilities for the uniform 5 MGD alternatives include a well field with production capacity of 6,291 acft/yr (15 wells at 300 gpm, including 2 back-up wells), brackish groundwater desalination plant with finished water capacity of 2,516 acft/yr, deep well injection of desalination concentrate, finished water tank, finished water pump station, and 20-inch transmission pipeline.

The facilities for the peak 20 MGD (5 MGD yearly average) alternatives include a well field with production capacity of 25,163 acft/yr (54 wells at 300 gpm, including 4 back-up wells), brackish groundwater desalination plant with finished water capacity of 10,065 acft/yr, deep well injection of desalination concentrate, finished water tank, finished water pump station, and 33-inch transmission pipeline.

The cost estimate for the strategy to deliver finished water at a uniform rate to the WW White Tank is shown in Table 4C.21.1-3. The cost estimate for the peaking strategy to deliver finished water for three months per year to the WW White Tank is shown in Table 4C.21.1-4. The WW White tank delivery alternative includes a pump station and transmission pipeline from the desalination plant to WW White tank. The transmission pipeline route follows the existing right-of-way for the SAWS ASR pipeline connecting the Twin Oaks WTP and the WW White tank. Additional costs for Distribution System Integration are not included in the estimate for the WW White tank alternative since the water is delivered directly into the existing distribution system.

The cost estimates for the strategy to deliver finished water the Twin Oaks WTP is shown in Table 4C.21.1-5. The cost estimates for the peaking strategy to deliver finished water for three months per year to the Twin Oaks WTP is shown in Table 4C.21.1-6. The Twin Oaks WTP delivery alternative includes a pump station and transmission pipeline from the desalination plant to the clearwell at the Twin Oaks WTP. Additional costs for Distribution System Integration are included in the estimate for the Twin Oaks WTP alternative since the water must be delivered from the Twin Oaks WTP into the SAWS distribution system as part of a larger integration project.

Table 4C.21.1-3
Cost Estimate Summary
Brackish Groundwater Desalination – Wilcox Aquifer
(WW White Tank Delivery, 5 MGD)
(Second Quarter 2002 Prices)

Item	***Estimated Costs for Facilities***
Capital Costs	
Pump Station (5.05 MGD)	$1,100,000
Transmission Pipeline (20 in dia., 14 miles)	$5,620,000
Well Field	$7,586,000
Desalination Water Treatment Plant (2.25 MGD)	$4,680,000
Deep Well Injection of Concentrate	$2,000,000
Total Capital Cost	**$20,986,000**
Engineering, Legal Costs and Contingencies	$7,081,000
Environmental & Archaeology Studies and Mitigation	$1,122,000
Land Acquisition and Surveying (102 acres)	$945,000
Interest During Construction (2 years)	$2,411,000
Total Project Cost	**$32,545,000**
Annual Costs	
Debt Service (6 percent, 30 years)	$2,364,000
Operation and Maintenance	
Pump Station, Well Field, and Distribution	$180,000
Desalination Water Treatment Plant	$617,000
Pumping Energy Costs (5,070,263 kW-hr @ 0.06 $/kW-hr)	$304,000
Total Annual Cost	**$3,465,000**
Available Project Yield (acft/yr)	5,662
Annual Cost of Water ($ per acft)	$612
Annual Cost of Water ($ per 1,000 gallons)	$1.88

Note: Cost estimate assumes 50% of brackish groundwater is sent to the desalination plant. The recovery rate for the desalination process is 80% with 20% of the brackish water rejected as concentrated brine.

Table 4C.21.1-4
Cost Estimate Summary
Brackish Groundwater Desalination – Wilcox Aquifer
(WW White Tank Delivery, 20 MGD Peak, 5 MGD Yearly Average)
(Second Quarter 2002 Prices)

Item	Estimated Costs for Facilities
Capital Costs	
Pump Station (20.2 MGD)	$3,304,000
Transmission Pipeline (33 in dia., 14 miles)	$9,927,000
Well Field	$29,992,000
Desalination Water Treatment Plant (9 MGD)	$14,028,000
Deep Well Injection of Concentrate	$4,000,000
Integration	$0
Total Capital Cost	**$61,251,000**
Engineering, Legal Costs and Contingencies	$20,991,000
Environmental & Archaeology Studies and Mitigation	$1,941,000
Land Acquisition and Surveying (242 acres)	$2,303,000
Interest During Construction (2 years)	$6,919,000
Total Project Cost	**$93,405,000**
Annual Costs	
Debt Service (6 percent, 30 years)	$6,786,000
Operation and Maintenance	
Pump Station, Well Field, and Distribution	$522,000
Desalination Water Treatment Plant	$882,000
Pumping Energy Costs (5,253,882 kW-hr @ 0.06 $/kW-hr)	$315,000
Total Annual Cost	**$8,505,000**
Available Project Yield (acft/yr)	5,662
Annual Cost of Water ($ per acft)	$1,502
Annual Cost of Water ($ per 1,000 gallons)	$4.61

Note: Cost estimate assumes 50% of brackish groundwater is sent to the desalination plant. The recovery rate for the desalination process is 80% with 20% of the brackish water rejected as concentrated brine.

Table 4C.21.1-5
Cost Estimate Summary
Brackish Groundwater Desalination – Wilcox Aquifer
(Twin Oaks WTP Delivery, 5 MGD)
(Second Quarter 2002 Prices)

Item	***Estimated Costs for Facilities***
Capital Costs	
Pump Station (5.05 MGD)	$887,000
Transmission Pipeline (20 in dia., 8 miles)	$3,336,000
Well Field	$7,586,000
Desalination Water Treatment Plant (2.25 MGD)	$4,680,000
Deep Well Injection of Concentrate	$2,000,000
Integration	$6,701,000
Total Capital Cost	**$25,190,000**
Engineering, Legal Costs and Contingencies	$8,667,000
Environmental & Archaeology Studies and Mitigation	$965,000
Land Acquisition and Surveying (79 acres)	$726,000
Interest During Construction (2 years)	$2,844,000
Total Project Cost	**$38,392,000**
Annual Costs	
Debt Service (6 percent, 30 years)	$2,789,000
Operation and Maintenance	
Pump Station, Well Field, and Distribution	$218,000
Desalination Water Treatment Plant	$617,000
Pumping Energy Costs (4,288,772 kW-hr @ 0.06 $/kW-hr)	$257,000
Total Annual Cost	**$3,881,000**
Available Project Yield (acft/yr)	5,662
Annual Cost of Water ($ per acft)	$685
Annual Cost of Water ($ per 1,000 gallons)	$2.10

Note: Cost estimate assumes 50% of brackish groundwater is sent to the desalination plant. The recovery rate for the desalination process is 80% with 20% of the brackish water rejected as concentrated brine.

Table 4C.21.1-6
Cost Estimate Summary
Brackish Groundwater Desalination – Wilcox Aquifer
(Twin Oaks WTP Delivery, 20 MGD Peak, 5 MGD Yearly Average)
(Second Quarter 2002 Prices)

Item	***Estimated Costs for Facilities***
Capital Costs	
Pump Station (20.2 MGD)	$2,639,000
Transmission Pipeline (33 in dia., 8 miles)	$6,000,000
Well Field	$29,992,000
Desalination Water Treatment Plant (9 MGD)	$14,028,000
Deep Well Injection of Concentrate	$4,000,000
Integration	$6,701,000
Total Capital Cost	**$63,360,000**
Engineering, Legal Costs and Contingencies	$21,925,000
Environmental & Archaeology Studies and Mitigation	$1,784,000
Land Acquisition and Surveying (220 acres)	$2,083,000
Interest During Construction (2 years)	$7,133,000
Total Project Cost	**$96,285,000**
Annual Costs	
Debt Service (6 percent, 30 years)	$6,995,000
Operation and Maintenance	
Pump Station, Well Field, and Distribution	$533,000
Desalination Water Treatment Plant	$882,000
Pumping Energy Costs (4,496,269 kW-hr @ 0.06 $/kW-hr)	$270,000
Total Annual Cost	**$8,680,000**
Available Project Yield (acft/yr)	5,662
Annual Cost of Water ($ per acft)	$1,533
Annual Cost of Water ($ per 1,000 gallons)	$4.70

4C.21.1.5 Implementation Issues

Implementation of the Wilcox aquifer brackish groundwater strategy includes the following issues:

- Verification of available groundwater water quantity and well productivity for the outcrop area of the Wilcox aquifer in Bexar County;
- Permitting Class 1 disposal well for deep well injection of desalination concentrate;
- Verification of Wilcox aquifer water quality for both concentrations of the dissolved constituents such as TDS, chloride, and sulfate; and to ensure that particulates that would require pretreatment removal such as iron or manganese are not present;
- Experience in operating and maintaining a desalination water treatment plant;
- Regulations by the TCEQ;
- Ensure no coordination with groundwater district is required; and
- Verification that desalinated Wilcox aquifer water is compatible with other water sources and will meet all water quality requirements in the end user's distribution system.

4C.21.2 Gulf Coast Aquifer

4C.21.2.1 Description of Water Management Strategy

This strategy is an extension of the Lower Guadalupe Water Supply Project (LGWSP) In-basin Use to include additional groundwater from the brackish area of the Gulf Coast aquifer in Refugio County. The strategy includes all facilities for the LGWSP with additional brackish groundwater facilities to provide 10,176 acft/yr of additional firm yield to the LGWSP. The brackish groundwater facilities include a well field with 1,000 gpm, 1,300 feet deep wells located in Refugio County as shown in Figure 4C.21.2-1. The average total dissolved solids (TDS) concentration for the brackish groundwater is estimated to be 1,200 mg/L. Desalination facilities are located adjacent to the well field and are sized to treat half the brackish water to produce a finished blended water supply that meets all potable water regulatory requirements including concentrations of the dissolved constituents TDS, chloride, and sulfate.

After desalination treatment and blending, the finished water from the brackish well field is delivered to the LGWSP transmission system for blending with the surface water and other non-brackish groundwater from the Gulf Coast aquifer for delivery to Bexar County.

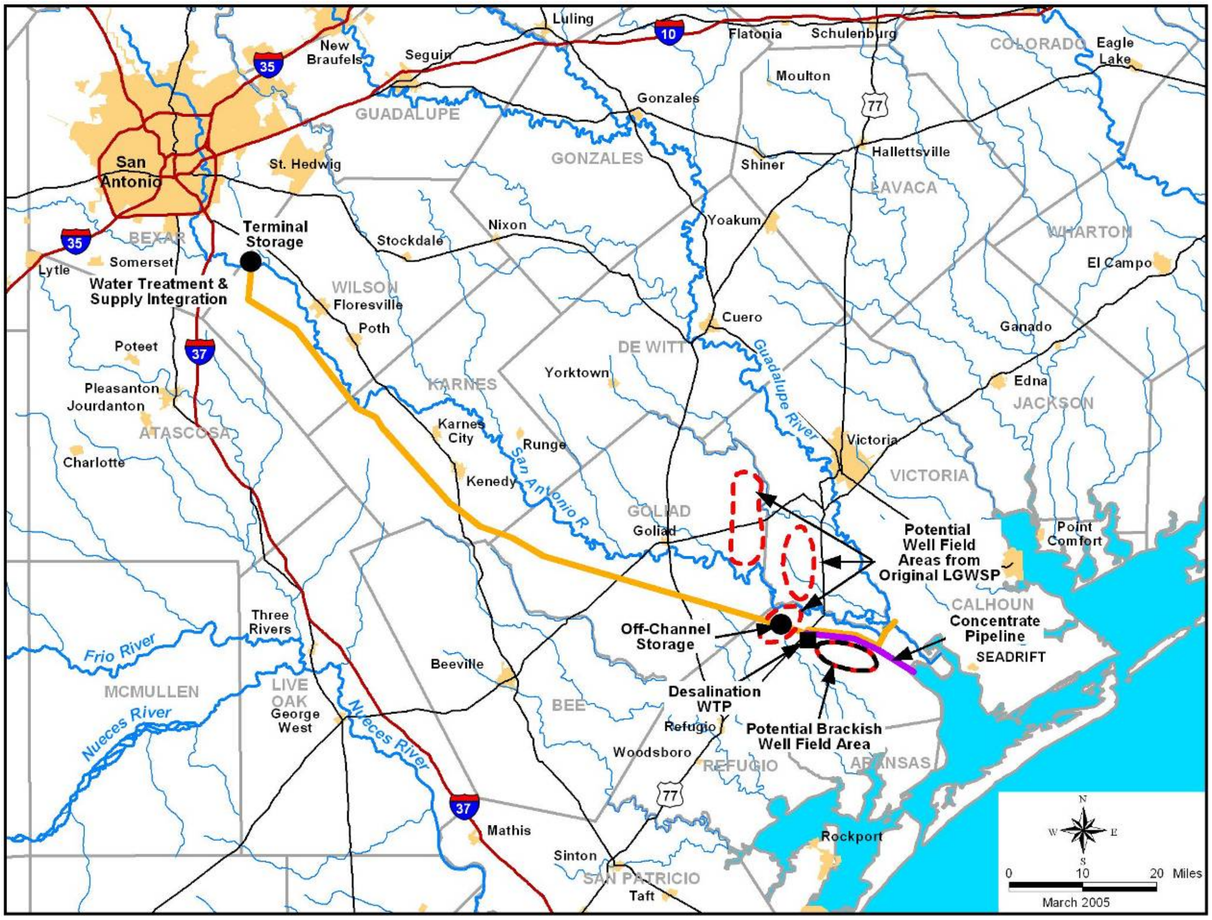


Figure 4C.21.2-1. Brackish Groundwater Desalination – Gulf Coast Aquifer

4C.21.2.2 Available Yield

The firm water availability or available project yield associated with the LGWSP water management strategy is 104,487 acft/yr, when the use of the GBRA/UCC water rights is considered an in-basin use as detailed for the LGWSP in Section 4C.8. The addition of a brackish well field in Refugio County with a maximum finished water production of 10,160 acft/yr increases the firm yield of the entire LGWSP (in-basin use) with brackish groundwater to 114,647 acft/yr. The increase in total project firm yield is essentially a one-to-one relationship with the additional maximum finished water production from brackish groundwater.

Some of the brackish groundwater drawn from the well field in Refugio County will be lost as desalination concentrate. Therefore, the actual maximum groundwater production from the brackish well field is 11,291 acft/yr, but 1,131 acft/yr is lost as desalination concentrate and is not included as part of the finished water production. The brackish groundwater usage is variable as necessary to provide firm yield for the overall LGWSP strategy.

4C.21.2.3 Environmental Issues

This strategy includes all facilities for LGWSP with addition of a brackish well field with a production capacity of 11,291 acft/yr, a brackish groundwater desalination plant, and a 16-mile desalination concentrate pipeline discharging to Hynes Bay. This discussion addresses only those issues associated with the added well field, desalination plant, and the concentrate pipeline. These features are located in Omernik's[4] Western Gulf Coastal Plain ecoregion.

The primary environmental issue related to brackish groundwater desalination that is not also a concern for the LGWSP is the construction of a concentrate pipeline from the desalination water treatment plant to Hynes Bay. The concentrate pipeline is 16 miles long. Half of the concentrate pipeline parallels the transmission pipeline from the confluence of the Guadalupe and San Antonio Rivers to an off-channel reservoir in Refugio County. Therefore, 8 miles of the concentrate pipeline shares a right-of-way with the off-channel reservoir transmission pipeline. The remaining 8 miles of concentrate pipeline will traverse Refugio County to Hynes bay and consist of a 30-ft right-of-way that would affect a total area of approximately 29 acres.

The desalination concentrate outfall into the bay may require multiple input locations or installation of a diffuser system to insure localized high concentrations of some constituents are not caused by discharge of the desalination concentrate. Surface water quality monitory results for Hynes Bay compiled as part of the Clean Rivers Program for the years 1993 through 2004 showed conductivity varied from 1,546 to 46,600 umhos/cm and averaged 25,000 umhos/cm. These conductivity values converted to TDS are roughly a range of 860 to 25,900 mg/L TDS and average of 13,900 mg/L TDS in Hynes Bay. The desalination concentrate to be discharged to the bay will have a TDS that averages around 6,000 mg/L. Therefore, under average conditions the addition of desalination concentrate will decrease the salinity of the bay.

The potential environmental effects resulting from the construction of a brackish groundwater desalination plant in the vicinity of Hynes/San Antonio Bay will be sensitive to the siting of the plant and its concentrate discharge pipeline location. Construction will temporarily disrupt shoreline and benthic habitats in the immediate vicinity, including wetlands and other sensitive areas. Of particular concern will be potential impacts to *Spartina* marshes and to

[4] Omernik, J. M, "Ecoregions of the conterminous United States," Annals of the Association of American Geographers, 77: 118-125, 1987.

seagrass beds. Discharge structure sites should be selected to avoid areas where organisms tend to concentrate. These include rock outcrops, man-made structures, the vicinities of tidal passes and the surf zone. It can be assumed that the permit process will at sometime require a (modeling) demonstration showing that the design of the discharge structure will be adequate to rapidly disperse the brine plume to ambient salinities within a relatively small mixing zone.

Many migratory birds are dependent on the quality of estuarine environments in order to complete the foraging and nesting of their migration. One of the most well known of the migratory birds is the Whooping Crane (*Grus Americana)*, which is listed as endangered by both USFWS and TPWD. A growing population of whooping cranes winter in and near the Aransas National Wildlife Refuge located adjacent to the Mesquite Bay and the southern and western portions of San Antonio Bay. This wintering population has grown from a low of only 16 birds in 1941 to a high of 216 birds in 2004. Detailed research studies by Texas A&M University are underway at this time to identify and better understand factors affecting whooping crane population. Two other migratory birds known to the San Antonio Bay area are listed as threatened by TPWD: the Reddish Egret (*Egretta rufescens*), and the Piping Plover (*Charadrius melodus*). The Piping Plover is also listed as threatened by USFWS.

Surveys for protected species should be conducted within the proposed construction corridors where preliminary evidence indicates their existence. Many of these species, such as the Texas Tortoise, the Texas Horned Lizard, and the Indigo Snake, are dependent on shrubland or riparian habitat. The Texas Garter Snake may be present in wetland habitat, and the Timber Rattlesnake, a threatened species, may be found in the riparian woody vegetation of the area.

The Wildlife Science Research and Diversity maps, which are maintained by TPWD, do report the occurrence of endangered, threatened, or rare species near the potential well field and pipeline right-of-way. One endangered species known to exist near the pipeline corridor is the Attwater's Greater Prairie Chicken in Refugio County. The Attwater's Greater Prairie Chicken prefers the coastal prairies grassland in area 0 to 24 inches in vegetation height. Coastal Gay Feather (*Liatris bracteata*), Plains Gumweed (*Grindelia oolepsis*), Elmendorf's Onion (*Allium elmendorfii*), Parks' Jointweed (*Polygonella parksii*), and Welder Machaeranthera (Psilactis heterocarpa) are all rare plants found in this area. Plant and animal species in the project area listed by the USFWS, and TPWD as endangered or threatened are presented in Table 4C.21.2-1. All species listed have habitat requirements or preferences that suggest they could be present within the project area.

Table 4C.21.2-1 Important Species Having Habitat or Known to Occur in Counties Potentially Affected by the Brackish Groundwater Desalination-Gulf Coast Aquifer*

Common Name	Scientific Name	Impact Value	Multiplier Based on Status	Adjusted Impact	Summary of Habitat Preference	Listing Entity USFWS[1]	Listing Entity TPWD[1]	Potential Occurrence in County
American Eel	*Anguilla rostrata*	0	1	0	Moist aquatic habitats.			Resident
American Peregrine Falcon	*Falco peregrinus anatum*	0	3	0	Open country; cliffs	DL	E	Nesting/Migrant
Arctic Peregrine Falcon	*Falco peregrinus tundrius*	0	2	0	Open country; cliffs	DL	T	Nesting/Migrant
Atlantic Hawksbill Sea turtle	*Eretmochelys imbricata*	0	3	0	Gulf and bay system.	LE	E	Migrant
Attwater's Greater Prairie-Chicken	*Tympanuchus cupido attwateri*	2	3	6	Coastal Prairies of Gulf Coastal Plain	LE	E	Nesting
Bald Eagle	*Haliaeetus leucocephalus*	0	2	0	Large Bodies of water with nearby resting sites	LT-PDL	T	Nesting/Migrant
Black Bear	*Usus americanus*	0	2	0	Mountains, broken country, woods, brushlands, forests	T/SA; NL	T	Resident
Black Lace Cactus	*Echinocereus reichenbachii var. albertii*	0	3	0	Grasslands, thorn shrublands, mesquite woodlands on sandy, somewhat saline soils on coastal prairie	LE	E	Resident
Black-Spotted Newt	*Notophthalmus meridionalis*	0	2	0	Ponds and resacas in south Texas		T	Resident
Brown Pelican	*Pelecanus occidentalis*	1	3	3	Coastal inlands for nesting, shallow gulf and bays for foraging	LE	E	Nesting/Migrant

Table 4C.21.2-1 (Continued)

Cave Myotis Bat	*Myotis velifer*	0	1	0	Roosts colonially in caves.			Resident
Coastal Gay Feather	*Liatris bracteata*	2	1	2	Black clay soils of midgrass grasslands on coastal prairie remnants.			Resident
Elmendorf's Onion	*Allium elmendorfii*	0	1	0	Endemic; deep sands derived from Queen City and similar Eocene formations			Resident
Green Sea Turtle	*Chelonia mydat*	0	2	0	Gulf and bay system.	LT	T	Migrant
Gulf Saltmarsh Snake	Nerodia clarkii	1	1	1	Brackish to saline coastal waters			Resident
Henslow's Sparrow	*Ammodramus henslowii*	1	1	1	Weedy fields, cut over areas; bare ground for running and walking			Nesting/Migrant
Indigo Snake	*Drymarchon corais erebennus*	1	2	2	Grass prairies and sand hills; usually thornbush woodland and mesquite savannah of coastal plain		T	Resident
Interior Least Tern	*Sterna antillarum athalassos*	0	3	0	Inland river sandbars for nesting and shallow water for foraging	LE	E	Nesting/Migrant
Jaguarundi	*Felis yagouaroundi*	0	3	0	South Texas thick brushlands, favors areas near water	LE	E	Resident
Kemp's Ridley Sea Turtle	*Lepidochelys kempii*	0	3	0	Gulf and bay system.	LE	E	Migrant
Keeled Earless Lizard	*Holbrookia propinqua*	0	1	0	Coastal dunes, Barrier islands and sandy areas			Resident
Leatherback Sea Turtle	*Dermochelys coriacea*	0	3	0	Gulf and bay system.	LE	E	Migrant
Loggerhead Sea Turtle	*Caretta caretta*	0	2	0	Gulf and bay system.	LT	T	Migrant
Louisiana Black Bear	*Ursus americanus luteolus*	0	2	0	Within historical range.	LT	T	
Mexican Treefrog	*Smilisca baudinii*	0	2	0	Subtropical woodlands, resacas.		T	Resident
Mountain Plover	*Charadrius montanus*	0	1	0	Non-breeding-shortgrass plains and fields, plowed fields and sandy deserts			Nesting/Migrant
Ocelot	*Felis pardalis*	0	3	0	Dense chaparral thickets; mesquite-thorn scrub and live oak mottes	LE	E	Resident

Table 4C.21.2-1 (Continued)

Opossum Pipefish	*Microphis brachyurus*	0	2	0	Brooding adults found in fresh or low salinity waters.		T	Resident
Piping Plover	*Charadrius melodus*	0	2	0	Beaches and flats of Coastal Texas	LT	T	Migrant
Plains Gumweed	*Grindelia oolepsis*	1	1	1	Early successional patches in coastal prairie on heavy clay soils, sometimes in disturbed habitats in urban areas			Resident
Plains Spotted Skunk	*Spilogale putorius interrupta*	0	1	0	Prefers wooded, brushy areas and tallgrass prairie, fields, prairies, croplands, fence rows, forest edges			Resident
Red Wolf	*Canis rufus*	0	3	0	Extirpated.	LE	E	
Reddish Egret	Egretta rufescens	0	2	0	Coastal inlands for nesting, coastal marshes for foraging		T	Migrant
Scarlet Snake	*Cemophora coccinea*	0	2	0	Sandy soils of East Texas, central and south Gulf Coast		T	Resident
Sennett's Hooded Oriole	*Icterus cucullatus sennetti*	0	1	0	Often builds nest of Spanish moss.			
Sheep Frog	*Hypopachus variolosus*	1	2	2	Deep sandy soils of Southeast Texas		T	Resident
Snowy Plover	*Charadrius alexandrinus*	0	1	0	Wintering Migrant on mud flats.			Migrant
Sooty Tern	*Sterna fuscata*	0	1	0	Catches small fish.			Resident
South Texas Siren (Lg. Form)	*Siren sp. 1*	0	2	0	Moist soils		T	Resident
Southern Yellow Bat	*Lasiurus ega*	0	2	0	Associated with trees.		T	Resident
Spot-Tailed Earless Lizard	*Holbrookia lacerata*	1	1	1	central & southern Texas; oak-juniper woodlands and mesquite-prickly pear			Resident
Texas Botteri's Sparrow	*Aimophila botterii texana*	1	2	2	Coastal lowlands and prairies.		T	Resident
Texas Diamondback Terrapin	*Malaclemys terrapin littoralis*	1	1	1	Bays, coastal marshes of the upper two-thirds of Texas Coast			Resident
Texas Horned Lizard	*Phrynosoma cornutum*	1	2	2	Varied, sparsely vegetated uplands, grass, cactus, brush		T	Resident

Table 4C.21.2-1 (Concluded)

Texas Scarlet Snake	*Cemophora coccinea lineri*	1	2	2	Mixed hardwood scrub		T	Resident
Texas Tortoise	*Gopherus berlandieri*	1	2	2	Open brush w/ grass understory; open grass/bare ground avoided; occupies shallow depressions at base of bush or cactus, underground burrows, under objects; active March through November		T	Resident
Tharp's rhododon	*Rhododon angulatus*	1	1	1	Deep, sandy soils in dunes.			Resident
Timber Rattlesnake	*Crotalus horridus*	1	2	2	Floodplains, upland pine, deciduous woodlands, riparian zones, abandoned farms, dense ground cover		T	Resident
Welder Machaeranthera	*Psilactis heterocarpa*	2	1	2	Coastal prairie; Shrub-infested grasslands and open mesquite-huisache woodlands			Resident
White-faced Ibis	*Plegadis chihi*	0	2	0	Prefers freshwater marshes.		T	Resident
White-tailed Hawk	*Buteo albicaudatus*	0	2	0	Coastal prairies, savannahs and marshes in Gulf coastal plain		T	Nesting/Migrant
Whooping Crane	*Grus americana*	0	3	0	Potential migrant	LE	E	Migrant
Wood Stork	*Mycteria americana*	0	2	0	Forages in prairie ponds, ditches, and shallow standing water formerly nested in TX		T	Migrant

[1] Texas Parks and Wildlife Department (TPWD), Unpublished 2005, March 2005, Data and Map Files of the Wildlife Science Research and Diversity Division maintained by TPWD, Austin, Texas.

- LE/LT=Federally Listed Endangered/Threatened
- E/SA, T/SA=Federally Listed Endangered/Threatened by Similarity of Appearance
- C1=Federal Candidate for Listing
- DL, PDL=Federally Delisted/Proposed for Delisting
- NL=not Federally Listed
- E, T=State Listed Endangered/Threatened
- PE, PT=Federally Proposed Endangered/ Threatened
- Blank = Rare, but no regulatory listing status

Cultural resources protection on public lands in Texas is afforded by the Antiquities Code of Texas (Title 9, Chapter 191, Texas Natural Resource Code of 1977), the National Historic Preservation Act (Pl96-515), and the Archeological and Historic Preservation Act (PL93-291). Based on the review of available records housed at the Texas Archeological Research Laboratory in Austin, no cultural resource sites appear to occur within the proposed well field, desalinization plant or concentrate pipeline area. Since the owner or controller of the project will likely be a political subdivision of the State of Texas (i.e., river authority, municipality, county, etc.), coordination with the Texas Historical Commission will also be required as part of the U.S. Army Corps of Engineers Wetland permitting program under the Clean Water Act.

4C.21.2.4 Engineering and Costing

The cost estimate for the LGWSP with Gulf Coast aquifer brackish groundwater desalination as a supplemental component is shown in Table 4C.21.2-1. The engineering and costing analysis includes all facilities for LGWSP – In-basin Use (Section 4C.7) with 91.5-mile 84-inch transmission pipeline from the off-channel storage to a terminal storage site in southern Bexar County (TS-6). Additional facilities include a brackish well field with production capacity of 11,291 acft/yr (8 wells at 1,000 gpm, including 1 back-up well), brackish groundwater desalination plant with finished water capacity of 4,516 acft/yr, and 16-mile 12-inch desalination concentrate pipeline discharging to Hynes Bay. The brackish groundwater supply is used to provide firm yield for the strategy as necessary, and therefore the maximum brackish water capacity is not continuously utilized. The average desalted brackish water contribution to the overall strategy is 4,814 acft/yr. The well field will require wells and a collector pipeline. Desalination water treatment will be provided at a plant located adjacent to the well field.

The Gulf Coast aquifer water total dissolved solids (TDS) concentration is estimated to average 1,200 mg/L. The required secondary Maximum Contaminant Level (MCL) for TDS is 1,000 mg/L. The estimate assumes that half the raw water from the well field is sent to the desalination plant to remove dissolved solids. The desalination plant recovery rate is 80% meaning that 80% of the water entering the desalination plant passes through as purified water and 20% of the water remains as concentrated brine containing the constituents removed from the purified water. The concentrate from the desalination process is discharged to Haynes Bay. The desalinated water is blended back with the untreated brackish water to produce a blended finished water that is 90% of the quantity of raw water produced from the well field. (50% not desalted + 50% desalted * 80% recovery = 90%). The blended finished water TDS concentration is about 670 mg/L. Pretreatment prior to the desalination process includes cartridge filtration with no additional pretreatment included for removal of particulates such as iron or manganese.

As shown in Table 4C.21.2-2, the LGWSP with a supplemental Brackish Groundwater Desalination component from the Gulf Coast Aquifer could provide a firm yield of 114,647 acft/yr at an annual unit cost of $1,012/acft/yr. The incremental firm yield associated with the brackish groundwater desalination component is 10,176 acft/yr and has an annual unit cost of $796/acft/yr.

4C.21.2.5 Implementation Issues

Implementation of the Gulf Coast aquifer brackish groundwater strategy includes the following issues:

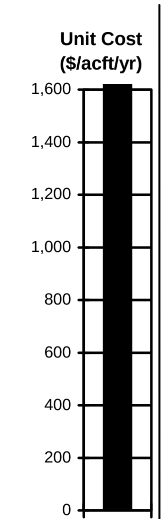
- Verification of available groundwater water quantity and well productivity for the Gulf Coast aquifer in the brackish portions of the aquifer in Refugio County;
- Permitting desalination concentrate discharge to Hynes Bay;
- Verification of the Gulf Coast aquifer water quality for both concentrations of the dissolved constituents such as TDS, chloride, and sulfate; and to ensure that particulates that would require pretreatment removal such as iron or manganese are not present;
- Experience in operating and maintaining a desalination water treatment plant;
- Regulations by the TCEQ;
- Coordination with landowners and groundwater conservation district; and
- Verification that desalinated Gulf Coast aquifer water is compatible with other water sources for treatment to meet all water quality requirements in the user’s distribution system.

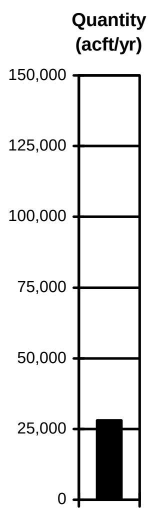
Table 4C.21.2-1
Cost Estimate Summary
Lower Guadalupe Water Supply Project with
Brackish Groundwater Desalination – Gulf Coast Aquifer
(Second Quarter 2002 Prices)

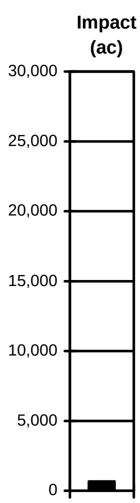
Item	***Estimated Costs for Facilities***
Capital Costs	
Off-Channel (2-25,000 acft reservoirs) and Terminal (10,570 acft reservoir) Storage	$82,534,000
Three Intake and Pump Stations (108, 259, and 102 MGD)	$44,351,000
Transmission Pipeline (84 in dia., 110 miles)	$282,636,000
Two Transmission Pump Stations (108 MGD each)	$20,899,000
Well Fields	$48,253,000
Water Treatment Plant (107.7 MGD)	$84,510,000
Desalination Water Treatment Plant (4.2 MGD)	$7,258,000
Concentrate Pipeline (12 in dia., 16 miles)	$3,241,000
Integration	$113,565,000
Total Capital Cost	**$687,247,000**
Engineering, Legal Costs and Contingencies	$226,243,000
Environmental & Archaeology Studies and Mitigation	$9,914,000
Land Acquisition and Surveying (4,717 acres)	$50,992,000
Interest During Construction (4 years)	$156,001,000
Total Project Cost	**$1,130,397,000**
Annual Costs	
Debt Service (6 percent, 30 years)	$72,055,000
Reservoir Debt Service (6 percent, 40 years)	$9,210,000
Operation and Maintenance	
Intake, Pipeline, Pump Station	$6,045,000
Dam and Reservoir	$1,238,000
Water Treatment Plant	$8,901,000
Desalination Water Treatment Plant	$1,017,000
Pumping Energy Costs (222,436,118 kW-hr @ 0.06 $/kW-hr)	$13,346,000
Purchase of Water (70,000 acft/yr @ 60.72 $/acft)	$4,250,000
Total Annual Cost	**$116,062,000**
Available Project Yield (acft/yr)	114,647
Annual Cost of Water ($ per acft)	$1,012
Annual Cost of Water ($ per 1,000 gallons)	$3.11

Note: Cost estimate assumes 50% of brackish groundwater is sent to the desalination plant. The recovery rate for the desalination process is 80% with 20% of the brackish water rejected as concentrated brine.

2006 South Central Texas Regional Water Plan
Water Management Strategy Summary Sheet







***Name: Seawater Desalination* – 25 MGD**

Description: This strategy includes desalting seawater from San Antonio Bay and conveying water to the major municipal demand center of the South Central Region. Facilities include a raw water intake and water treatment plant near Seadrift, brine transmission and off-shore disposal system, 42-inch treated water transmission pipeline and associated pump stations for delivery of water a distance of approximately 126 miles to south Bexar County, and distribution system improvements for integration of the additional supply.

***Decade Needed*:** 2050 – 2060

Cost, Quantity of Water, and Land Impacted

Unit Cost of Water:	**1,767**	**$/acft/yr**	**Treated Water Distributed**
Quantity of Water:	**28,004**	**acft/yr**	**Reliability = Firm**
Land Impacted:	**673**	**acres**	

Additional Considerations per Regional Water Planning Guidelines

Environmental Factors:

Wintering population of endangered Whooping Cranes at the Aransas National Wildlife Refuge located across San Antonio Bay from the proposed intake site near Seadrift. Potential effects of diversions on bay salinity and estuarine habitat and species. Pipeline could traverse Attwater Prairie Chicken habitat.

Impacts on Water Resources:

Potential benefit to instream flows in the San Antonio River due to increased discharge of treated effluent.

Impacts on Agricultural & Natural Resources:

Temporary impacts due to construction of pipeline.

Other Relevant Factors per SCTRWPG:

Confirmation of technology and values used in developing costs prior to implementation. Perceived to have fewer associated environmental effects than typical fresh surface water supplies.

Comparison of Strategies to Meet Needs:

High unit cost, but potential for large drought-proof water supply. Unit cost is approximately 50 percent treatment and 50 percent conveyance. No conflicts with other recommended water management strategies.

Interbasin Transfer Issues:

Not applicable.

Third-Party Impacts of Voluntary Transfers:

Not applicable.

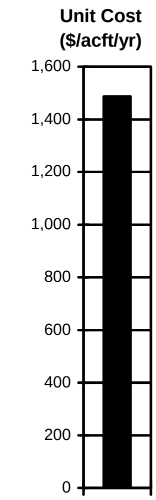
Regional Efficiency:

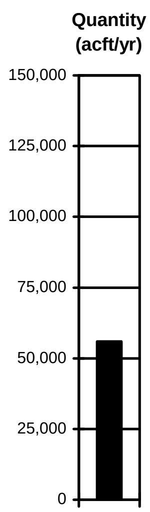
Additional surface water supply without reductions in instream flows or freshwater inflows to the Guadalupe Estuary. Shared pipeline alignment with other recommended water management strategies.

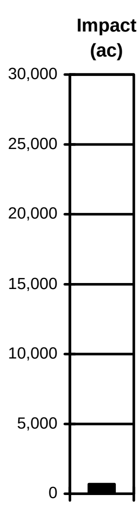
Water Quality Considerations:

Integration of desalinated water with different corrosion chemistry may require conditioning of water to meet distribution system stability requirements. Operational treatment costs may be substantially reduced at source water salinities less than the assumed 25 ppt.

2006 South Central Texas Regional Water Plan
Water Management Strategy Summary Sheet







Name: Seawater Desalination **– 50 MGD**

Description: This strategy includes desalting seawater from San Antonio Bay and conveying water to the major municipal demand center of the South Central Region. Facilities include a raw water intake and water treatment plant near Seadrift, brine transmission and off-shore disposal system, 60-inch treated water transmission pipeline and associated pump stations for delivery of water a distance of approximately 126 miles to south Bexar County, and distribution system improvements for integration of the additional supply.

Decade Needed**:** 2050 – 2060

Cost, Quantity of Water, and Land Impacted

Unit Cost of Water:	**1,487**	**$/acft/yr**	**Treated Water Distributed**
Quantity of Water:	**56,008**	**acft/yr**	**Reliability = Firm**
Land Impacted:	**693**	**acres**	

Additional Considerations per Regional Water Planning Guidelines

Environmental Factors:

Wintering population of endangered Whooping Cranes at the Aransas National Wildlife Refuge located across San Antonio Bay from the proposed intake site near Seadrift. Potential effects of diversions on bay salinity and estuarine habitat and species. Pipeline could traverse Attwater Prairie Chicken habitat.

Impacts on Water Resources:

Potential benefit to instream flows in the San Antonio River due to increased discharge of treated effluent.

Impacts on Agricultural & Natural Resources:

Temporary impacts due to construction of pipeline.

Other Relevant Factors per SCTRWPG:

Confirmation of technology and values used in developing costs prior to implementation. Perceived to have fewer associated environmental effects than typical fresh surface water supplies.

Comparison of Strategies to Meet Needs:

High unit cost, but potential for large drought-proof water supply. Unit cost is approximately 55 percent treatment and 45 percent conveyance. No conflicts with other recommended water management strategies.

Interbasin Transfer Issues:

Not applicable.

Third-Party Impacts of Voluntary Transfers:

Not applicable.

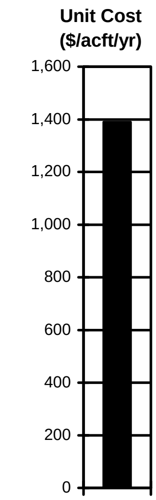
Regional Efficiency:

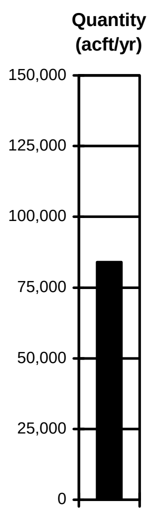
Additional surface water supply without reductions in instream flows or freshwater inflows to the Guadalupe Estuary. Shared pipeline alignment with other recommended water management strategies.

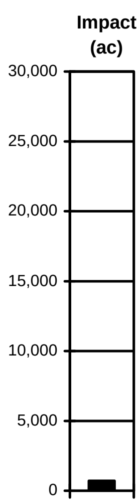
Water Quality Considerations:

Integration of desalinated water with different corrosion chemistry may require conditioning of water to meet distribution system stability requirements. Operational treatment costs may be substantially reduced at source water salinities less than the assumed 25 ppt.

2006 South Central Texas Regional Water Plan
Water Management Strategy Summary Sheet







Name: Seawater Desalination – 75 MGD

Description: This strategy includes desalting seawater from San Antonio Bay and conveying water to the major municipal demand center of the South Central Region. Facilities include a raw water intake and water treatment plant near Seadrift, brine transmission and off-shore disposal system, 72-inch treated water transmission pipeline and associated pump stations for delivery of water a distance of approximately 126 miles to south Bexar County, and distribution system improvements for integration of the additional supply.

***Decade Needed*:** 2050 – 2060

Cost, Quantity of Water, and Land Impacted

Unit Cost of Water:	**1,390**	**$/acft/yr**	**Treated Water Distributed**
Quantity of Water:	**84,012**	**acft/yr**	**Reliability = Firm**
Land Impacted:	**700**	**acres**	

Additional Considerations per
Regional Water Planning Guidelines

Environmental Factors:

Wintering population of endangered Whooping Cranes at the Aransas National Wildlife Refuge located across San Antonio Bay from the proposed intake site near Seadrift. Potential effects of diversions on bay salinity and estuarine habitat and species. Pipeline could traverse Attwater Prairie Chicken habitat.

Impacts on Water Resources:

Potential benefit to instream flows in the San Antonio River due to increased discharge of treated effluent.

Impacts on Agricultural & Natural Resources:

Temporary impacts due to construction of pipeline.

Other Relevant Factors per SCTRWPG:

Confirmation of technology and values used in developing costs prior to implementation. Perceived to have fewer associated environmental effects than typical fresh surface water supplies.

Comparison of Strategies to Meet Needs:

High unit cost, but potential for large drought-proof water supply. Unit cost is approximately 56 percent treatment and 44 percent conveyance. No conflicts with other recommended water management strategies.

Interbasin Transfer Issues:

Not applicable.

Third-Party Impacts of Voluntary Transfers:

Not applicable.

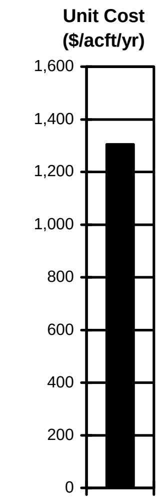
Regional Efficiency:

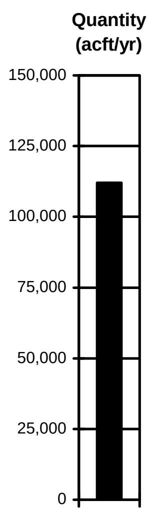
Additional surface water supply without reductions in instream flows or freshwater inflows to the Guadalupe Estuary. Shared pipeline alignment with other recommended water management strategies.

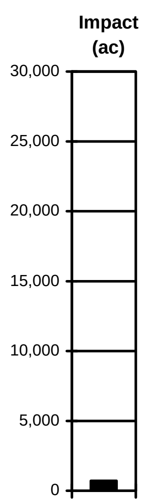
Water Quality Considerations:

Integration of desalinated water with different corrosion chemistry may require conditioning of water to meet distribution system stability requirements. Operational treatment costs may be substantially reduced at source water salinities less than the assumed 25 ppt.

2006 South Central Texas Regional Water Plan
Water Management Strategy Summary Sheet







Name: Seawater Desalination – 100 MGD

Description: This strategy includes desalting seawater from San Antonio Bay and conveying water to the major municipal demand center of the South Central Region. Facilities include a raw water intake and water treatment plant near Seadrift, brine transmission and off-shore disposal system, 84-inch treated water transmission pipeline and associated pump stations for delivery of water a distance of approximately 126 miles to south Bexar County, and distribution system improvements for integration of the additional supply.

***Decade Needed*:** 2050 – 2060

Cost, Quantity of Water, and Land Impacted

Unit Cost of Water:	**1,305**	**$/acft/yr**	**Treated Water Distributed**
Quantity of Water:	**112,016**	**acft/yr**	**Reliability = Firm**
Land Impacted:	**706**	**acres**	

Additional Considerations per Regional Water Planning Guidelines

Environmental Factors:

Wintering population of endangered Whooping Cranes at the Aransas National Wildlife Refuge located across San Antonio Bay from the proposed intake site near Seadrift. Potential effects of diversions on bay salinity and estuarine habitat and species. Pipeline could traverse Attwater Prairie Chicken habitat.

Impacts on Water Resources:

Potential benefit to instream flows in the San Antonio River due to increased discharge of treated effluent.

Impacts on Agricultural & Natural Resources:

Temporary impacts due to construction of pipeline.

Other Relevant Factors per SCTRWPG:

Confirmation of technology and values used in developing costs prior to implementation. Perceived to have fewer associated environmental effects than typical fresh surface water supplies.

Comparison of Strategies to Meet Needs:

High unit cost, but potential for large drought-proof water supply. Unit cost is approximately 58 percent treatment and 42 percent conveyance. No conflicts with other recommended water management strategies.

Interbasin Transfer Issues:

Not applicable.

Third-Party Impacts of Voluntary Transfers:

Not applicable.

Regional Efficiency:

Additional surface water supply without reductions in instream flows or freshwater inflows to the Guadalupe Estuary. Shared pipeline alignment with other recommended water management strategies.

Water Quality Considerations:

Integration of desalinated water with different corrosion chemistry may require conditioning of water to meet distribution system stability requirements. Operational treatment costs may be substantially reduced at source water salinities less than the assumed 25 ppt.

4C.22 Seawater Desalination

4C.22.1 Description of Water Management Strategy

Desalting seawater from the Gulf of Mexico in the vicinity of San Antonio Bay is a potential source of freshwater supplies for municipal and industrial use. This section presents desalination information for a range of quantities so that a range of costs can be considered. The strategy will be a large-scale desalt plant with finished water capacity ranging from 25 to 100 MGD (28,004 to 112,016 acft/yr) drawing saline water from San Antonio Bay with a conveyance system for delivery of treated water to the major municipal water demand center of the South Central Texas Region.

The desalination treatment plant is located adjacent to San Antonio Bay near the City of Seadrift and the treated water delivery location is south Bexar County as shown in Figure 4C.22-1. The desalination process produces a concentrated brine that is conveyed out to the open Gulf of Mexico for diffusion in deep water. The treatment plant location and concentrate pipeline are shown in Figure 4C.22-2.

4C.22.1.1 General Desalination Background

The commercially available processes that are currently used to desalt seawater and brackish groundwater to produce potable water are:

- Distillation (thermal) Processes; and
- Membrane (non-thermal) Processes.

The following sections describe each of these processes and discuss a number of issues that should be considered before selecting a process for desalination of seawater.

4C.22.1.2 Distillation (Thermal) Processes

Distillation processes produce purified water by vaporizing a portion of the saline feedstock to form steam. Since the salts dissolved in the feedstock are nonvolatile, they remain unvaporized and the steam formed is captured as a pure condensate. Distillation processes are normally very energy-intensive, quite expensive, and are generally used for large-scale desalination of seawater. Heat is usually supplied by steam produced by boilers or from a turbine power cycle used for electric power generation. Distillation plants are commonly co-sited with power plants.

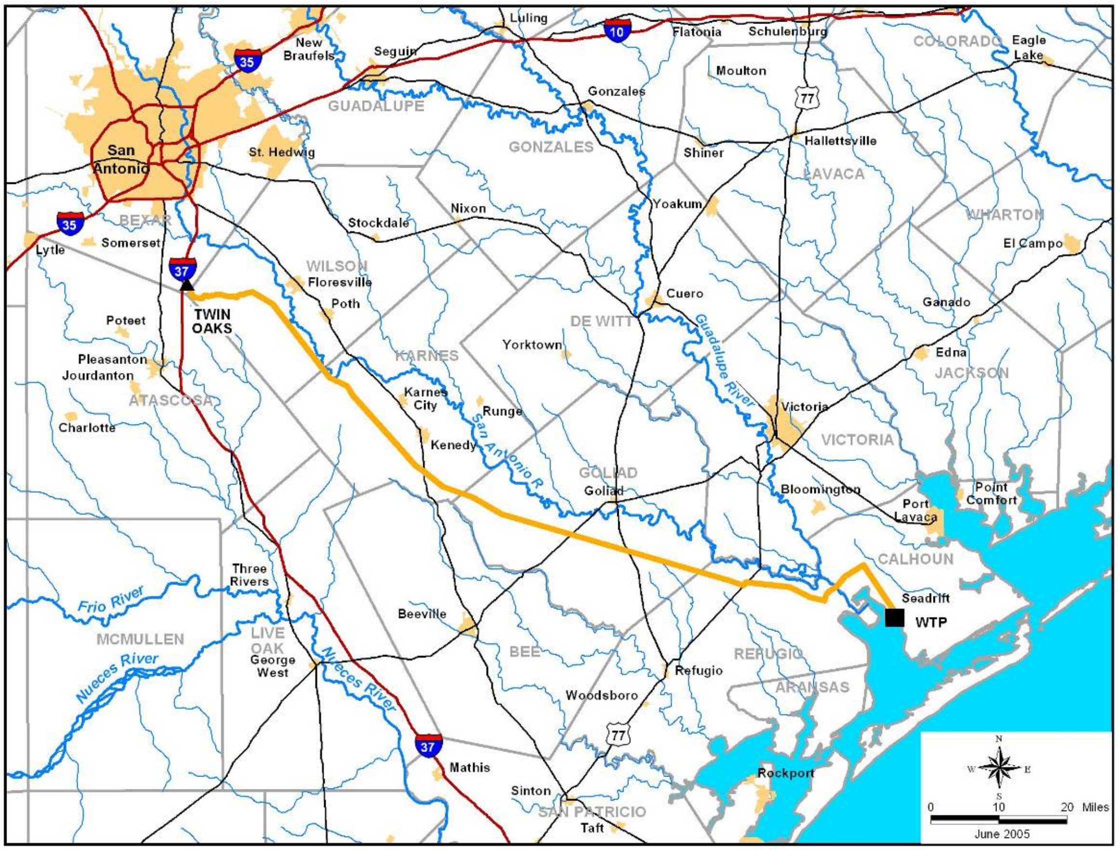


Figure 4C.22-1. Seawater Desalination Location Map

In general, for a specific plant capacity, the equipment in distillation plants tends to be much larger than membrane desalination equipment. However, distillation plants do not have the stringent feedwater quality requirements of membrane plants. Due to the relatively high temperatures required to evaporate water, distillation plants have high-energy requirements, making energy a large factor in their overall water cost. Their high operating temperatures can result in scaling (precipitation of minerals from the feedwater), which reduces the efficiency of the evaporator processes, because once an evaporator system is constructed, the size of the exchange area and the operating profile are fixed, leaving energy transfer as a function of only the heat transfer coefficient. Therefore, any scale that forms on heat exchanger surfaces reduces heat transfer coefficients. Under normal circumstances, scale can be controlled by chemical inhibitors, which inhibit but do not eliminate scale, and by operating at temperatures of less than 200°F.

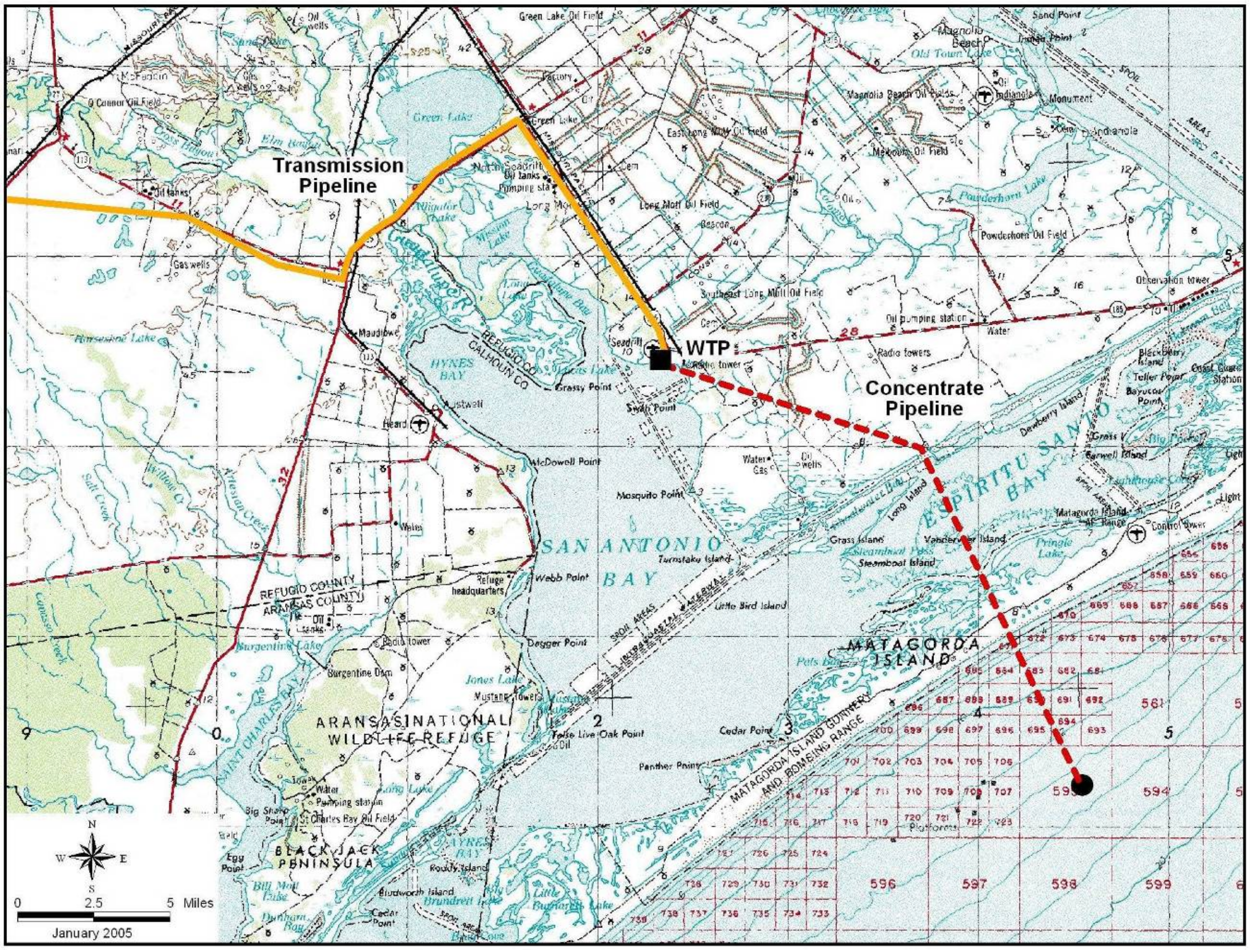


Figure 4C.22-2. Treatment Plant and Concentrate Pipeline Location

Distillation product water recoveries normally range from 15 to 45 percent, depending on the process. The product water from these processes is nearly mineral free, with very low TDS (less than 25 mg/L). However, this product water is extremely aggressive and is too corrosive to meet the Safe Drinking Water Act (SDWA) corrosivity standards without post-treatment. Product water can be stabilized by chemical treatment or by blending with other potable water.

The three main distillation processes in use today are Multistage Flash Evaporation (MSF), Multiple Effect Distillation (MED), and Vapor Compression (VC). All three of these processes utilize an evaporator vessel that vaporizes and condenses the feedstock. The three processes differ in the design of the heat exchangers in the vessels and in the method of heat introduction into the process. Since there are no distillation processes in Texas that can be shown as comparable installations, distillation will not be further considered herein. However, there are membrane desalination operations in Texas, so the following discussion and analyses are based upon information from the use of membrane technology for desalination.

4C.22.1.3 Membrane (Non-thermal) Processes

The two types of membrane processes use either pressure, as in reverse osmosis, or electrical charge, as in electrodialysis reversal, to reduce the mineral content of water. Both processes use semi-permeable membranes that allow selected ions to pass through while other ions are blocked. Electrodialysis reversal (EDR) uses direct electrical current applied across a vessel to attract the dissolved salt ions to their opposite electrical charges. EDR can desalinate brackish water with TDS up to several thousand mg/L, but energy requirements make it economically uncompetitive for seawater, which typically contains approximately 35,000 mg/L TDS. As a result, only reverse osmosis (RO) is used for seawater desalination.

RO utilizes a semi-permeable membrane that limits the passage of salts from the saltwater side to the freshwater side of the membrane. Electric motor driven pumps or steam turbines (in dual-purpose installations) provide the 800 to 1,200 psi pressure to overcome the osmotic pressure and drive the freshwater through the membrane, leaving a waste stream of brine/concentrate. The basic components of an RO plant include pre-treatment, high-pressure pumps, membrane assemblies, and post-treatment. Pretreatment is essential because feedwater must pass through very narrow membrane passages during the process and suspended materials, biological growth, and some minerals can foul the membrane. As a result, virtually all suspended solids must be removed and the feedwater must be pre-treated so precipitation of minerals or growth of microorganisms does not occur on the membranes. This is normally accomplished by various levels of filtration and the addition of various chemical additives and inhibitors. Post-treatment of product water is usually required prior to distribution to reduce its corrosivity and to improve its aesthetic qualities. Specific treatment is dependent on product water composition.

A "single pass/stage" seawater RO plant will produce water with a TDS of 300 to 500 mg/L, most of which is sodium and chloride. The product water will be corrosive, but this may be acceptable, if a source of blending water is available. If not, and if post-treatment is required, the various post-treatment additives may cause the product water to exceed the desired TDS levels. In such cases, or when better water quality is desired, a "two pass/stage" RO system is used to produce water typically in the 200 mg/L TDS range. In a two pass RO system, the product water from the first RO pass/stage is further desalted in a second RO pass/stage, and the water from the second pass is blended with water from the first pass.

Recovery rates up to 45 percent are common for a two-pass/stage seawater RO facility. RO plants, which comprise about 47 percent of the world's desalting capacity, range from a few gallons per day to 35 MGD. The largest RO seawater plant in the United States is the 25-MGD plant in Tampa Bay, Florida. The current domestic and worldwide trend is for the adoption of RO when a single purpose seawater desalting plant is to be constructed. RO membranes have been improved significantly over the past two decades (i.e., the membranes have been improved with respect to efficiency, longer life, and lower prices).

Table 4C.22-1.
Municipal Use Desalt Plants in Texas
(>25,000 gpd and as of June 2004)

Location	***Source***	***Total Capacity (MGD)***	***Desalt Capacity (MGD)***	***Membrane Type***[1]
Abilene, City of	Surface Water	5	3	RO
Bardwell, City of	Groundwater	0.12	0.12	RO
Bayside, City of	Groundwater	0.15	0.15	RO
Brownsville, City of	Groundwater	7.5	7.5	RO
Burleson County MUD 1	Groundwater	0.43	0.43	RO
Country View Estates	Groundwater	0.18	0.18	RO
Dell City, City of	Groundwater	0.11	0.11	EDR
Electra, City of	Groundwater	2.23	2.23	RO
El Paso County Water Auth.	Groundwater	2.29	2.29	RO
Ft. Stockton, City of	Groundwater	6.5	3.67	RO
Granbury, City of	Surface Water	0.35	0.35	EDR
Haciendas del Norte (El Paso)	Groundwater	0.12	0.12	RO
Homestead MUD (El Paso)	Groundwater	0.1	0.1	RO
Kenedy, City of	Groundwater	2.86	0.72	RO
Lake Granbury	Surface Water	10	10	RO
Lake Granbury	Surface Water	5	5	EDR
Los Ybanez, City of	Groundwater	0.11	0.11	RO
Oak Trail Shores	Lake Water	0.72	0.72	EDR
Robinson, City of	Surface Water	2.38	2.38	RO
Seadrift, City of	Groundwater	0.24	0.17	RO
Sherman, City of	Surface Water	5.6	5.6	EDR
Sportsman's World	Surface Water	0.17	0.17	RO
Tatum, City of	Groundwater	1.14	1.14	RO
Texas Resort Co.	Surface Water	0.144	0.144	EDR

[1] RO = Reverse Osmosis EDR = Electrodialysis Reversal

4C.22.1.4 Examples of Relevant Existing Desalt Projects

Tampa, Florida: The water utility, Tampa Bay Water, has selected a 30-year design, build, operate, and own (DBOO) proposal to construct a nominal 25 MGD seawater desalt plant. The plant will use RO as the desalt process. The proposal included total capitalization and operations costs for producing high quality drinking water (chlorides less than 100 mg/L). The total cost to Tampa Bay Water in the original proposal was to be $2.08 per 1,000 gallons ($678 per acft) on a 30-year average, with first year cost being $1.71 per 1,000 gallons ($557 per acft). However, subsequent issues with the original design including significant problems in obtaining adequate pretreatment have increased the projected total cost to Tampa Bay Water by $0.72 per 1,000 gallons for a total projected cost of $2.80 per 1,000 gallons ($912 per acft) on a 30-year average.[1] The results of Tampa Bay's competition has attracted international interest in the current cost profile of desalting seawater for drinking water supply, since these costs are only about one-half the levels experienced in previous desalination projects.

Tampa Bay Water selected the winning proposal from four DBOO proposals submitted, which ranged from $2.08 to $2.53 per 1,000 gallons. The factors listed below may be all or partially responsible for these seemingly low costs:

1. Salinity at the Tampa Bay sites ranges from 25,000 to 30,000 mg/L, lower than the more common 35,000 mg/L for seawater. RO cost is sensitive to salinity.
2. The power cost, which is interruptible, is below $0.04 per kilowatt-hour (kWh).
3. Construction cost savings through using existing power plant canals for intake and concentrate discharge.
4. Economy of scale at 25 MGD.
5. Amortizing over 30 years.
6. Use of tax-exempt bonds for financing.

The Tampa bids contrast with another current large-scale desalination project in which distillation is proposed. The current desalt project of the Singapore Public Utility Board, which proposes a 36 MGD multi-stage flash distillation plant, will cost an estimated $5.76 per 1,000 gallons ($1,877 per acft) for the first year operation in 1998 dollars.[2]

Large-Scale Demonstration Seawater Desalination in Texas: The Texas Water Development Board (TWDB) funded several studies to evaluate the feasibility of large-scale desalination in Texas. As part of this initiative, the City of Corpus Christi, Freeport, and the

[1] Associated Press, "Tampa Bay Water to Hire Group to Fix Desalination Plant," September 21, 2004.
[2] Desalination & Water Reuse Quarterly, vol. 7/4, Feb/Mar 1998.

Lower Rio Grande Valley-Brownsville were selected as potential locations for large-scale seawater desalination and feasibility studies were conducted for each of these locations. The draft feasibility reports were submitted to TWDB in August 2004 and indicated that the demonstration seawater desalination projects for the three locations are technically feasible. However, all three draft reports indicate that the estimated total costs for capital and O&M of the proposed projects will exceed the cost of alternative sources of drinking water at these locations[3].

The study evaluated several potential strategies and the assumptions utilized in the cost estimates were selected by the individual study participants. Table 4C.22-2 shows a summary of the cost estimates with the costs for each study modified using the Regional Planning assumptions (power cost = $0.06 / kWh, Debt Service = 6 percent, 30 years). The Total Project Cost and Total O&M Cost in Report were reported in the summary evaluation prepared by the TWDB.

Table 4C.22-2.
Cost Summary for TWDB Large-Scale Seawater Demonstration in Texas
(Costs Adjusted to Regional Planning Format)
(2004 Prices)

Item	*Brownsville (25 MGD)*	*Corpus Christi (25 MGD)*	*Freeport - BRA (10 MGD)*
Total Project Cost	**$151,388,000**	**$196,600,000**	**$93,183,000**
Debt Service (6 percent, 30 years)	$10,998,173	$14,282,776	$6,769,644
Power Usage (kWh)	127,400,000	112,391,661	NA
Power Cost (@$0.06/kWh)	7,644,000	6,743,500	NA
Power Cost in Report (@$0.0545, @$0.065, NA)	6,943,000	7,305,458	3,162,200
Total O&M Cost in Report	11,776,000	17,515,000	7,364,100
Adjusted Total O&M Cost	**$12,477,000**	**$16,953,042**	**$6,803,900**
Total Annual Cost	**$23,475,173**	**$31,235,818**	**$14,133,744**
Available Project Yield (acft/yr)	**28,004**	**28,004**	**11,201**
Annual Cost of Water ($ per acft)	**$838**	**$1,115**	**$1,262**
Annual Cost of Water ($ per 1,000 gallons)	**$2.57**	**$3.42**	**$3.87**

Source: Texas Water Development Board, “The Future of Desalination in Texas, Volume I, Biennial Report on Seawater Desalination,” December 2004.

[3] Texas Water Development Board, “The Future of Desalination in Texas Volume I, Biennial Report on Seawater Desalination”, December 2004.

4C.22.2 Available Yield

Seawater from San Antonio Bay and the Gulf of Mexico is an unlimited quantity within the context of a supply for the South Central Texas Region. For the purpose of developing this strategy in which seawater from the bay is desalted to develop a significant drinking water supply for the major urban area in the region, it is assumed that the availability of water is unlimited and that its cost is zero prior to extraction from the source.

4C.22.3 Environmental Issues

4C.22.3.1 Seawater Desalination

The proposed location of the desalination facilities is near Seadrift on San Antonio Bay, which is part of the estuary of the San Antonio and Guadalupe Rivers (Figure 4C.22-2). This location would take advantage of the lower energy requirement of the desalination process at the lower salinity levels of the upper estuary, although the variable salinity can adversely affect operations. Estuaries, which serve as critical habitat and spawning grounds for many marine species and migratory birds, are marine environments maintained in a brackish state by the inflow of freshwater from rivers and streams. The high productivity characteristic of estuaries arises from the abundance of terrigenous nutrient input, shallow water, and the ability of a few marine species to exploit environments continually stressed by low, variable salinities, temperature extremes, and, on occasion, low dissolved oxygen concentrations.

The potential environmental effects resulting from the construction of a desalination plant in the vicinity of San Antonio Bay will be sensitive to the siting of the plant and its intake and locations. Construction of either will temporarily disrupt shoreline and benthic habitats in the immediate vicinity, including wetlands and other sensitive areas and operation of the intake will result in some impingment and entrainment of aquatic organisms. Impingement takes place when organisms are trapped against intake screens by the force of the water passing into the intake structure. Entrainment occurs when organisms are drawn through the water intake structure into the pump and transport system. Organisms that become impinged or entrained are normally relatively small organisms, including early life stages of fish and shellfish. Impingement can result in descaling or other physical damage, and starvation, exhaustion or asphyxiation when the organism cannot escape the intake structure. Entrained organisms are subject to mechanical, thermal, or toxic stress (e.g., biocides or low dissolved oxygen concentrations) as they pass through the system. In the case of either impingement or entrainment, a substantial proportion of the affected individuals will be killed or subjected to significant harm. Minimization of impingement and entrainment by appropriate site selection and through the use of appropriate screening technology must be considered during system design as part of the overall effort to avoid or minimize potential impacts to the esturine environment.

Since the brine concentrate discharge point is planned to be located about 13 miles offshore, impacts of this feature on the estuary would be limited to the impacts of pipeline construction on bay bottom habitats. Of particular concern will be potential impacts to *Spartina* marshes and to seagrass beds. Discharge structure sites should be selected to avoid areas where organisms tend to concentrate. These include rock outcrops, man-made structures, the vicinities of tidal passes and the surf zone. It can be assumed that the permit process will at sometime require a (modeling) demonstration showing that the design of the discharge structure will be adequate to rapidly disperse the brine plume to ambient salinities within a relatively small mixing zone.

A desalination facility using 50 MGD of feedwater would process about 154 acft of bay water per day, or up to 4,800 acft/month. This is a small amount (2.5 percent) compared to historical San Antonio Bay (Guadalupe Estuary) average inflows (195,000 acft/month). Four percent of median inflows (119,000 acft/month), and 1.3 percent of bay volume (360,000 acft). Only during low flow periods would the water withdrawal from desalination be substantial relative to inflows. For example, the 4,800 acft/month would be about 12 percent of monthly inflows during months so dry that they occur only 10 percent of the time, and is roughly equivalent to the lowest monthly inflow recorded for the estuary. Bay volumes, inflows, and tidal exchanges with the Gulf of Mexico are so large relative to this alternative that substantial impacts to overall salinity gradients, or to the delivery of nutrients and sediment are not realistic.

Many migratory birds are dependent on the quality of estuarine environments in order to complete the foraging and nesting of their migration. One of the most well known of the migratory birds is the Whooping Crane (*Grus Americana),* which is listed as endangered by both USFWS and TPWD. A growing population of whooping cranes winter in and near the Aransas National Wildlife Refuge located adjacent to the Mesquite Bay and the southern and western portions of San Antonio Bay. This wintering population has grown from a low of only 16 birds in 1941 to a high of 216 birds in 2004. Detailed research studies by Texas A&M University are underway at this time to identify and better understand factors affecting whooping crane population. Two other migratory birds known to the San Antonio Bay area are listed as threatened by TPWD: the Reddish Egret (*Egretta rufescens*), and the Piping Plover (*Charadrius melodus*). The Piping Plover is also listed as threatened by USFWS.

The water transmission pipeline between San Antonio Bay and Bexar County would be approximately 126 miles long. A construction right-of-way of approximately 140-feet wide would affect a total area of approximately 2,138 acres. The construction of the pipeline would include the clearing and removal of woody vegetation. A 40-foot wide right-of-way corridor, free of woody vegetation and maintained for the life of the project, would total 611 acres. The proposed pipeline route would traverse three of Omernik's[4] ecoregions: the Western Gulf Coastal Plain, the East Central Texas Plains, and the westernmost reaches of the Texas Blackland Prairie. In addition, the Guadalupe River is listed by TPWD as a Ecologically Significant River and Stream Segment. Surveys for protected species should be conducted within the proposed construction corridors where preliminary evidence indicates their existence. Many of these species, such as the Texas Tortoise, the Texas Horned Lizard, and the Indigo Snake, are dependent on shrubland or riparian habitat. The Texas Garter Snake may be present in wetland habitat, and the Timber Rattlesnake, a threatened species, may be found in the riparian woody vegetation of the area.

Destruction of potential habitat can be avoided by selecting a corridor through previously disturbed areas, such as croplands. Selection of a pipeline right-of-way alongside the existing habitat could also be beneficial to some wildlife by providing edge habitat; however, the majority of these areas are small and fragmented, so care should be taken to ensure minimum impacts.

The Wildlife Science Research and Diversity maps, which are maintained by TPWD, do report the occurrence of endangered, threatened, or rare species near the potential pipeline right-of-way. One endangered species known to exist near the pipeline corridor is the Attwater's Greater Prairie Chicken in Goliad and Refugio Counties. The Attwater's Greater Prairie Chicken prefers the coastal prairies grassland in area 0 to 24 inches in vegetation height. Big red sage (Salvia penstemonoides), Coastal Gay Feather (*Liatris bracteata*), Plains Gumweed (*Grindelia oolepsis*), Elmendorf's Onion (*Allium elmendorfii*), Parks' Jointweed (*Polygonella parksii*), Threeflower Broomweed (*Thurovia triflora*) and Welder Machaeranthera (Psilactis heterocarpa) are all rare plants found in this corridor. In addition, the Texas Diamondback Terrapin, a species

[4] Omernik, J.M., "Ecoregions of the Conterminous United States," Annals of the Association of American Geographers, 77:118-125, 1987.

of concern, has been documented within 1 mile of the proposed project route. Plant and animal species in the project area listed by the USFWS, and TPWD as endangered or threatened are presented in Table 4C.22-3. All species listed have habitat requirements or preferences that suggest they could be present within the project area.

Cultural resources protection on public lands in Texas is afforded by the Antiquities Code of Texas (Title 9, Chapter 191, Texas Natural Resource Code of 1977), the National Historic Preservation Act (Pl96-515), and the Archeological and Historic Preservation Act (PL93-291). Based on the review of available records housed at the Texas Archeological Research Laboratory in Austin, six cultural resource sites appear to occur within the proposed project area. Table 4C.22-4 lists archeological sites within a one-mile corridor of the Seawater Desalination project area. Considering that the owner or controller of the project will likely be a political subdivision of the State of Texas (i.e. river authority, municipality, county, etc.), they will be required to coordinate with the Texas Historical Commission regarding if the project will affect waters of the United States or wetlands, the project sponsor will also be required to coordinate with the U.S. Army Corps of Engineers regarding impacts to cultural resources.

4C.22.4 Engineering and Costing

4C.22.4.1 Seawater Desalination at San Antonio Bay

This water management strategy provides for a major desalination water treatment plant on the Texas coast and the infrastructure for transferring potable water from the coast to the major municipal demand center of the South Central Texas Region. The entire strategy consists of the intake, water treatment plant, storage tanks, pumping stations and a 126-mile pipeline. The water treatment plant component includes pretreatment necessary to ensure normal life and efficiency of the reverse osmosis membranes. This water management strategy is presented in terms of four firm capacities that demonstrate the potential economy of scale over a range from 25 MGD to 100 MGD.

Desalination treatment cost estimates are based on recent similar desalination treatment plant construction experience and feasibility studies. This approach takes advantage of the development of membrane technology and the resulting reduction in capital and operating costs in comparison to previously available technology. During the past 15 years, the price and

Table 4C.22-3.
Important Species* Having Habitat or Known to Occur in Counties Potentially Affected by Desalination of Seawater

Common Name	Scientific Name	Impact Value	Multiplier Based on Status	Adjusted Impact	Summary of Habitat Preference	Listing Entity USFWS[1]	Listing Entity TPWD[1]	Potential Occurrence in County
American Eel	*Anguilla rostrata*	1	1	1	Moist aquatic habitats.			Resident
American Peregrine Falcon	*Falco peregrinus anatum*	0	3	0	Open country; cliffs	DL	E	Nesting/ Migrant
Arctic Peregrine Falcon	*Falco peregrinus tundrius*	0	2	0	Open country; cliffs	DL	T	Nesting/Migrant
Atlantic Hawksbill Sea turtle	*Eretmochelys imbricata*	1	3	3	Gulf and bay system.	LE	E	Migrant
Attwater's Greater Prairie-Chicken	*Tympanuchus cupido attwateri*	2	3	6	Coastal Prairies of Gulf Coastal Plain	LE	E	Nesting
Bald Eagle	*Haliaeetus leucocephalus*	2	2	4	Large Bodies of water with nearby resting sites	LT-PDL	T	Nesting/Migrant
Big Red Sage	*Salvia penstemonoides*	2	1	2	Moist Creek and stream bed edges; historic; introduced in native plant nursery trade			Resident
Black Bear	*Usus americanus*	0	2	0	Mountains, broken country, woods, brushlands, forests	T/SA; NL	T	Resident
Black Lace Cactus	*Echinocereus reichenbachii var. albertii*	1	3	3	Grasslands, thorn shrublands, mesquite woodlands on sandy, somewhat saline soils on coastal prairie	LE	E	Resident
Black-Spotted Newt	*Notophthalmus meridionalis*	1	2	2	Ponds and resacas in south Texas		T	Resident
Brown Pelican	*Pelecanus occidentalis*	0	3	0	Coastal inlands for nesting, shallow gulf and bays for foraging	LE	E	Nesting/Migrant
Cave Myotis Bat	*Myotis velifer*	0	1	0	Roosts colonially in caves.			Resident
Coastal Gay Feather	*Liatris bracteata*	2	1	2	Black clay soils of midgrass grasslands on coastal prairie remnants.			Resident
Corkwood	*Leitneria floridana*	1	1	1	Small shrub, found in narrow zone between brackish marsh and freshwater areas.			Resident
Elmendorf's Onion	*Allium elmendorfii*	1	1	1	Endemic; deep sands derived from Queen City and similar Eocene formations			Resident

Table 4C.22-3 continued

Eskimo Curlew	*Numenius borealis*	1	3	3	Grasslands, pastures.	LE	E	Nonbreeding Resident
Green Sea Turtle	*Chelonia mydat*	1	2	2	Gulf and bay system.	LT	T	Migrant
Guadalupe Bass	*Micropterus treculi*	2	1	2	Clear flowing streams			Resident
Gulf Saltmarsh Snake	*Nerodia clarkii*	0	1	0	Brackish to saline coastal waters			Resident
Henslow's Sparrow	*Ammodramus henslowii*	1	1	1	Weedy fields, cut over areas; bare ground for running and walking			Nesting/Migrant
Indigo Snake	*Drymarchon corais erebennus*	1	2	2	Grass prairies and sand hills; usually thornbush woodland and mesquite savannah of coastal plain		T	Resident
Interior Least Tern	*Sterna antillarum athalassos*	1	3	3	Inland river sandbars for nesting and shallow water for foraging	LE	E	Nesting/Migrant
Jaguarundi	*Felis yagouaroundi*	0	3	0	South Texas thick brushlands, favors areas near water	LE	E	Resident
Kemp's Ridley Sea Turtle	*Lepidochelys kempii*	1	3	3	Gulf and bay system.	LE	E	Migrant
Keeled Earless Lizard	*Holbrookia propinqua*	1	1	1	Coastal dunes, Barrier islands and sandy areas			Resident
Leatherback Sea Turtle	*Dermochelys coriacea*	1	3	3	Gulf and bay system.	LE	E	Migrant
Loggerhead Sea Turtle	*Caretta caretta*	1	2	2	Gulf and bay system.	LT	T	Migrant
Louisiana Black Bear	*Ursus americanus luteolus*	0	2	0	Within historical range.	LT	T	
Maculated Manfreda Skipper	*Stallingsia maculosus*	1	1	1	Fast erratic flight, larvae feed inside a leaf shelter, pupate in cocoon made of leaves & silk			Resident
Mexican Treefrog	*Smilisca baudinii*	1	2	2	Subtropical woodlands, resacas.		T	Resident
Mountain Plover	*Charadrius montanus*	1	1	1	Non-breeding-shortgrass plains and fields, plowed fields and sandy deserts			Nesting/Migrant
Ocelot	*Felis pardalis*	1	3	3	Dense chaparral thickets; mesquite-thorn scrub and live oak mottes	LE	E	Resident
Opossum Pipefish	*Microphis brachyurus*	1	2	2	Brooding adults found in fresh or low salinity waters.		T	Resident
Parks' Jointweed	*Polygonella parksii*	2	1	2	South Texas Plains; subherbaceous annual in deep loose sands, spring-summer			Resident
Piping Plover	*Charadrius melodus*	0	2	0	Beaches and flats of Coastal Texas	LT	T	Migrant
Plains Gumweed	*Grindelia oolepsis*				Early successional patches in coastal prairie on heavy clay soils, sometimes in disturbed habitats in urban areas			Resident

Table 4C.22-3 continued

Plains Spotted Skunk	*Spilogale putorius interrupta*	1	1	1	Prefers wooded, brushy areas and tallgrass prairie, fields, prairies, croplands, fence rows, forest edges			Resident
Red Wolf	*Canis rufus*	0	3	0	Extirpated.	LE	E	
Reddish Egret	*Egretta rufescens*	0	2	0	Coastal inlands for nesting, coastal marshes for foraging		T	Migrant
Runyon's Water Willow	*Justicia runyonii*	1	1	1	Openings in subtropical woodlands.			Resident
Scarlet Snake	*Cemophora coccinea*	1	2	2	Sandy soils of East Texas, central and south Gulf Coast		T	Resident
Sennett's Hooded Oriole	*Icterus cucullatus sennetti*	1	1	1	Often builds nest of Spanish moss.			
Sheep Frog	*Hypopachus variolosus*	1	2	2	Deep sandy soils of Southeast Texas		T	Resident
Snowy Plover	*Charadrius alexandrinus*	0	1	0	Wintering Migrant on mud flats.			Migrant
Sooty Tern	*Sterna fuscata*	1	2	2	Catches small fish.			Resident
South Texas Siren (Lg. Form)	*Siren sp. 1*	1	2	2	Moist soils		T	Resident
Southern Yellow Bat	*Lasiurus ega*	0	2	0	Associated with trees.		T	Resident
Spot-Tailed Earless Lizard	*Holbrookia lacerata*	1	1	1	central & southern Texas; oak-juniper woodlands and mesquite-prickly pear			Resident
Texas Asaphomyian Tabanid Fly	*Asaphomyia texanus*	1	1	1	Found near slow-moving water, eggs laid on objects near water; larvae are aquatic, adults prefer shady areas; feed on nectar and pollen			Resident
Texas Botteri's Sparrow	*Aimophila botterii texana*	1	2	2	Coastal lowlands and prairies.		T	Resident
Texas Diamondback Terrapin	*Malaclemys terrapin littoralis*	0	1	0	Bays, coastal marshes of the upper two-thirds of Texas Coast			Resident
Texas Garter Snake	*Thamnophis sirtalis annectens*	1	1	1	Varied, especially wet areas; bottomlands and pastures			Resident
Texas Horned Lizard	*Phrynosoma cornutum*	1	2	2	Varied, sparsely vegetated uplands, grass, cactus, brush		T	Resident
Texas Tortoise	*Gopherus berlandieri*	1	2	2	Open brush w/ grass understory; open grass/bare ground avoided; occupies shallow depressions at base of bush or cactus, underground burrows, under objects; active March through November		T	Resident
Tharp's rhododon	*Rhododon angulatus*	0	1	0	Deep, sandy soils in dunes.			Resident
Threeflower broomweed	*Thurovia triflora*	1	1	1	Endemic, black clay soils.			Resident

Table 4C.22-3 continued

Timber Rattlesnake	*Crotalus horridus*	1	2	2	Floodplains, upland pine, deciduous woodlands, riparian zones, abandoned farms, dense ground cover		T	Resident
Welder Machaeranthera	*Psilactis heterocarpa*	2	1	2	Coastal prairie; Shrub-infested grasslands and open mesquite-huisache woodlands			Resident
White-faced Ibis	*Plegadis chihi*	0	2	0	Prefers freshwater marshes.		T	Resident
White-tailed Hawk	*Buteo albicaudatus*	1	2	2	Coastal prairies, savannahs and marshes in Gulf coastal plain		T	Nesting/Migrant
Whooping Crane	*Grus americana*	0	3	0	Potential migrant	LE	E	Migrant
Wood Stork	*Mycteria americana*	0	2	0	Forages in prairie ponds, ditches, and shallow standing water formerly nested in TX		T	Migrant

[1] Texas Parks and Wildlife Department (TPWD), Unpublished 2005, March 2005, Data and Map Files of the Wildlife Science Research and Diversity Division maintained by TPWD, Austin, Texas.

* LE/LT=Federally Listed Endangered/Threatened E/SA, T/SA=Federally Listed Endangered/Threatened by Similarity of Appearance
C1=Federal Candidate for Listing DL, PDL=Federally Delisted/Proposed for Delisting NL=not Federally Listed E, T=State Listed Endangered/Threatened
PE, PT=Federally Proposed Endangered/ Threatened Blank = Rare, but no regulatory listing status

Table 4C.22-4. Previously Recorded Sites within 1-mile Corridor of the Proposed Seawater Desalination Project Area

Sites	41CL1
	41CL10
	41CL13
	41CL70
	41CL73
	41WN66

operating costs of membranes have declined due to improvements in materials and manufacturing. This contrasts with recent experience with conventional water treatment technology (i.e., costs for conventional water treatment technologies have not been influenced greatly by equipment innovations).

The basic assumptions made to determine the size and characteristics of the components of this seawater desalination strategy are listed in Table 4C.22-5. A 126-mile pipeline route from the desalination plant adjacent to San Antonio Bay near Seadrift to south Bexar County was assumed. The pumping capacities are equal to the nominal plant capacities, except for the raw water intake, which includes the full raw water quantity that is separated into desalinated finished water and concentrated brine in the plant. A conveyance line to carry the concentrated brine offshore is also included in the costs. A concentrate pump station is not included because it

Table 4C.22-5.
Engineering Assumptions for Seawater Desalination

Parameter	*Assumption*	*Description*
Raw water salinity	25,000 mg/L	Intake located near Seadrift
Finished water chlorides	100 mg/L	
Treatment capacities	25, 50, 75, 100 MGD	
Concentrate Pipeline Length	23 miles total (10 miles on land, 13 miles submerged)	Diffused in open Gulf
RO Recovery Rate	60 percent	
Power cost	$0.06 per kWh	Assume interruptible power
Pipeline diameter	42", 60", 72", 84"	
Booster storage	5 percent of flow	More than 1 hour storage to avoid in-line pumps
Number of booster stations	2	

is assumed that the residual pressure from the desalination process is utilized to convey the concentrate offshore.

The treatment and delivery components and respective sizes and capacities are summarized in Table 4C.22-6. The brine concentrate capacities for each nominal plant capacity are based on a recovery rate of 60 percent. This means that of the 100 percent of flow taken from San Antonio Bay at the plant intake, 60 percent is desalted and 40 percent is returned to the Gulf as concentrated brine *via* a route approximately 23 miles long from the plant location through the barrier island.

Table 4C.22-6.
Capacities for Seawater Desalination Plant

Item/Facility	*Nominal Water Treatment Plant Capacity*			
	25 MGD	*50 MGD*	*75 MGD*	*100 MGD*
Intake Pump Station (MGD)	42	83	125	167
Intake Pipeline Diameter (inches)	48	72	84	102
Desalination Water Treatment Plants				
Plant Intake (seawater) (MGD)	42	83	125	167
Desalted Product Water (drinking water) (MGD)	25	50	75	100
Brine Discharge (MGD)	17	33	50	67
Brine Discharge Pipeline Diameter (inches)	30	42	54	66
Desalted Product Water (MGD)	25	50	75	100
Pump Station at Plant and Each Booster Station (gpm)	17,361	34,722	52,083	69,444
Finished Water Pipeline Diameter (inches)	42	60	72	84
Storage at Booster Pump Stations (MG, each)	1.25	2.5	3.75	5.0

The estimated costs to desalt seawater range from $889 per acft for the 25 MGD size plant to $760 per acft for the 100 MGD size plant (Table 4C.22-7). The treatment costs include the water treatment plant (pretreatment and RO desalination), raw water intake, and concentrate discharge to the open Gulf. The pretreatment portion of the plant is essentially a full conventional surface water plant to remove solids from the raw water prior to the RO desalination process. There is some economy of scale in the treatment process with larger processes in the pretreatment and RO desalination components. Also, there are greater economies of scale for components such as the intake and concentrate pump stations and pipelines.

There are some economies of scale with increasing capacity to convey the treated water to the municipal demand center. Over the range from 25 MGD to 100 MGD the conveyance unit costs decrease from about $878 per acft for the 25 MGD size project to $546 per acft for the 100 MGD size project (Table 4C.22-7). The estimated total desalination treatment and conveyance cost from San Antonio Bay to the major municipal demand center of the South Central Texas Region decreases from $1,767 per acft ($5.42 per 1,000 gallons) for the 25 MGD size project to $1,305 per acft ($4.01 per 1,000 gallons) for the 100 MGD size project (Table 4C.22-7).

For a conservative cost estimating purposes the salinity of the raw water drawn from San Antonio Bay near Seadrift was assumed to consistently be 25,000 mg/L of total dissolved solids, which is on the upper end of historically observed salinity in this area of the bay. One study of salinity during the period 1968 to 1987 reported mean salinity of 5,640 mg/L in San Antonio Bay near Seadrift[5]. To provide firm yield of desalinated bay water, the desalination facilities should be constructed for the maximum anticipated salinity of 24,000 mg/L. Therefore, the capital costs would not decrease with lower mean salinity. However, if the mean salinity of the raw water delivered to the desalination plant is much less than the maximum, then the operations and maintenance costs may be significantly less than the costs shown in Table 4C.22-7. The primary cost savings for desalinating lower salinity water is the decrease in electrical power required due to an increase in the RO recovery rate and a decrease in the required pumping pressure to pass the desalinated water through the RO membranes. The decrease in cost to desalinate bay water

[5] Longley, W.L., ed. "Freshwater inflows to Texas bays and estuaries: ecological relationships and methods for determination of needs", TWDB and TPWD, 1994.

with mean salinity of 5,640 mg/L versus the costs shown in Table 4C.22-7 would be approximately $132 per acft ($0.41 per 1,000 gallons).

4C.22.5 Implementation Issues

4C.22.5.1 Seawater Desalination

Implementation of this water management strategy requires overcoming several financial, environmental, and technological impediments. The capital cost is likely to be a somewhat serious limitation. The cost estimate shows that while the treatment cost, based on recent Tampa experience and other feasibility studies for a planned 25 MGD desalination facility may be competitive, transferring water from the coast makes the total cost quite high in relation to other water management strategies.

There are several environmental issues that must be considered. The first is the location of the intake in San Antonio Bay. It will be an advantage to take slightly lower salinity water, similar to Tampa, rather than Gulf water. However, to accomplish this means that dilution with freshwater from the San Antonio and Guadalupe Rivers is necessary. Studies will need to be performed to ensure that the removal of the somewhat diluted bay water causes no harmful effects on plant and animal life in San Antonio Bay. Another issue with the desalt plant is the disposal of the concentrated brine created from the desalination process. Disposal would have to occur at a location and in a manner that also did not disrupt plant or animal life in the Bay or in the Gulf. A further complication is the permitting of a 126-mile pipeline across rivers, highways, and private rural and urban property.

Technological issues include: (1) confirming that desalination as proposed with membranes is the appropriate technology; (2) confirming that blending desalted seawater with the other water sources in the municipal demand distribution system can be successfully accomplished; and (3) obtaining an adequate source of electric power to drive the desalination process using membranes. The cost model on which this strategy is based corresponds fairly closely with the costs developed for three large-scale seawater desalination strategies recently evaluated by the TWDB.[6] The treatment costs for a 25 MGD seawater desalination plant in the TWDB study ranged from $778 per acft to $1,133 per acft compared to $889 per acft shown in Table 4C.22-7 for the 25 MGD alternative.

[6] Texas Water Development Board, "The Future of Desalination in Texas Volume I, Biennial Report on Seawater Desalination", December 2004.

Table 4C.22-7.
Cost Estimate Summary for
Desalination of Seawater
(Second Quarter 2002 Prices)

Item	*Estimated Costs 25 MGD*	*Estimated Costs 50 MGD*	*Estimated Costs 75 MGD*	*Estimated Costs 100 MGD*
Capital Costs				
Water Treatment Plant (Pretreatment and Desal)	$72,011,000	$129,272,000	$184,509,000	$239,581,000
Concentrate Disposal	$26,464,000	$43,279,000	$55,046,000	$66,197,000
Transmission Pump Stations	$17,148,000	$23,524,000	$30,055,000	$34,777,000
Transmission Pipeline	$115,979,000	$169,196,000	$237,391,000	$277,714,000
Integration	$33,175,000	$66,350,000	$86,825,000	$107,300,000
Total Capital Cost	**$264,777,000**	**$431,621,000**	**$593,826,000**	**$725,569,000**
Engineering, Legal Costs and Contingencies	$86,873,000	$142,608,000	$195,970,000	$240,063,000
Environmental & Archaeology Studies and Mitigation	$9,576,000	$11,559,000	$13,727,000	$15,787,000
Land Acquisition and Surveying (673 acres)	$6,485,000	$6,693,000	$6,768,000	$6,833,000
Interest During Construction (2.5 years)	$36,771,000	$59,249,000	$81,030,000	$98,826,000
Total Project Cost	**$404,482,000**	**$651,730,000**	**$891,321,000**	**$1,087,078,000**
Annual Costs				
Debt Service (6 percent, 30 years)	$29,385,000	$47,347,000	$64,753,000	$78,975,000
Operation and Maintenance				
Pipeline, Pump Stations, Tank, Distribution	$2,222,000	$3,437,000	$4,622,000	$5,476,000
Water Treatment Plants Except Energy	$6,848,000	$13,481,000	$19,329,000	$25,253,000
WTP Energy Costs (@$0.06/kWh)	$6,413,000	$12,819,000	$19,225,000	$25,633,000
Finished Water Pumping Energy Costs (@$0.06/kWh)	$4,607,000	$6,222,000	$8,835,000	$10,898,000
TOTAL				
Total Annual Cost	**$49,475,000**	**$83,306,000**	**$116,764,000**	**$146,235,000**
Annual Cost of Water ($ per acft)	**$1,767**	**$1,487**	**$1,390**	**$1,305**
Annual Cost of Water ($ per 1,000 gallons)	**$5.42**	**$4.56**	**$4.26**	**$4.01**
TREATMENT ONLY				
Total Annual Cost	**$24,896,000**	**$45,692,000**	**$65,397,000**	**$85,083,000**
Available Project Yield (acft/yr)	**28,004**	**56,008**	**84,012**	**112,016**
Annual Cost of Water ($ per acft)	**$889**	**$816**	**$778**	**$760**
Annual Cost of Water ($ per 1,000 gallons)	**$2.73**	**$2.50**	**$2.39**	**$2.33**
CONVEYANCE ONLY				

Total Annual Cost	**$24,579,00 0**	**$37,614,00 0**	**$51,368,00 0**	**$61,152,000**
Annual Cost of Water ($ per acft)	**$878**	**$672**	**$611**	**$546**
Annual Cost of Water ($ per 1,000 gallons)	**$2.69**	**$2.06**	**$1.88**	**$1.68**

Substantial verification of technology would need to be accomplished prior to building this project. Blending differing treated waters is critical for the wellbeing of the customers and the distribution system. The characteristics of the desalted water are likely to be dramatically different from other drinking water in the major municipal demand center of the South Central Texas Region. Considerable investigation would be needed to determine if additional conditioning of the desalinated seawater would be required to make the new water source compatible with existing distribution systems. Conditioning of the desalinated seawater may include addition of alkalinity and hardness to bring the corrosion chemistry closer to other existing water sources.

Finally, in spite of recent improvements in membrane technology, desalting seawater will require large amounts of electric power (Au79). Normally, this need is met by locating desalination plants near power plants. Future costs of electric power, however, are highly uncertain and represent a very significant component of annual operating costs for this strategy.

Requirements Specific to Water Rights

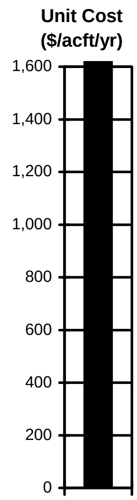
1. It will be necessary to obtain these permits:
   a. TCEQ Water Right permit.
   c. GLO Sand and Gravel Removal permits.
   d. GLO Easement for use of state-owned land.
   e. Coastal Coordination Council review.
   f. TPWD Sand, Gravel, and Marl permit.
2. Permitting, at a minimum, will require these studies:
   a. Assessment of changes in instream flows and freshwater inflows to bays and estuaries.
   b. Habitat mitigation plan.
   c. Environmental studies.
   d. Cultural resources.
3. Other Considerations:
   a. Water compatibility testing, including biological and chemical characteristics will need to be performed.

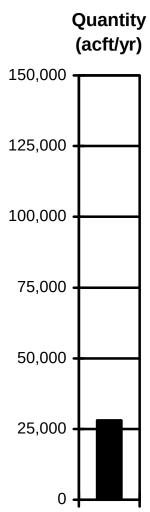
Requirements Specific to Pipelines

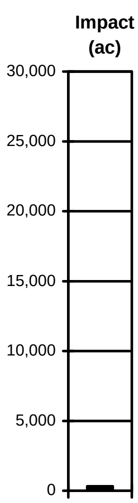
1. Necessary permits:
   a. USACE Sections 10 and 404 dredge and fill permits for stream crossings.
   b. GLO Sand and Gravel Removal permits.
   c. TPWD Sand, Gravel, and Marl permit for river crossings.

2. Right-of-way and easement acquisition.
3. Crossings:
   a. Highways and railroads
   b. Creeks and rivers
   c. Other utilities

2006 South Central Texas Regional Water Plan
Water Management Strategy Summary Sheet







Name: Inter-regional Seawater Desalination

Description: A cooperative water supply with desalted seawater for Corpus Christi in exchange for diversion of firm yield from the Choke Canyon Reservoir/ Lake Corpus Christi (CCR/LCC) System to the major municipal demand center of the South Central Region. Facilities include a seawater desalination water treatment plant in Corpus Christi, a raw water intake at Choke Canyon Reservoir, transmission pump station, 42-inch 63-mile raw water transmission pipeline, water treatment plant in south Bexar County, and improvements for integration of the additional supply.

***Decade Needed*:** 2050 – 2060

Cost, Quantity of Water, and Land Impacted

Unit Cost of Water:	**1,727**	**$/acft/yr**	**Treated Water Distributed**
Quantity of Water:	**28,004**	**acft/yr**	**Reliability = Firm**
Land Impacted:	**316**	**acres**	

Additional Considerations per Regional Water Planning Guidelines

Environmental Factors:

Potential effects of diversions on bay salinity and estuarine habitat and species. Selection of facility sites and pipeline routes to minimize impacts on endemic species and cultural resources.

Impacts on Water Resources:

Potential decrease of instream flows in the Nueces River and Lake Corpus Christi. Potential benefit to instream flows in the San Antonio River due to increased discharge of treated effluent.

Impacts on Agricultural & Natural Resources:

Temporary impacts due to construction of pipeline.

Other Relevant Factors per SCTRWPG:

Confirmation of desalination technology and values used in developing costs prior to implementation. Willingness of affected Nueces River water suppliers to consider development of cooperative water supply with the South Central Texas Region. Agreement(s) between Corpus Christi, NRA, SAWS, and USBR.

Comparison of Strategies to Meet Needs:

High unit cost that is comparable to seawater desalination from San Antonio Bay (SCTN-17).

Interbasin Transfer Issues:

Water rights permits for CCR would need to be amended to allow for use in San Antonio River Basin. However, parts of Bexar County are located in the Nueces River Basin so permit amendment can be authorized by Executive Director of TCEQ.

Third-Party Impacts of Voluntary Transfers:

Not applicable.

Regional Efficiency:

Delayed implementation of seawater desalination until driven by increased Corpus Christi demand may decrease strategy costs because “other costs” for debt on existing facilities that will become redundant in Corpus Christi will be reduced.

Water Quality Considerations:

Integration of desalinated water for Corpus Christi with different corrosion chemistry may require conditioning of water to meet distribution system stability requirements.

(This page intentionally left blank.)

4C.23 Inter-Regional Seawater Desalination

4C.23.1 Description of Water Management Strategy

The development of a cooperative water supply with the City of Corpus Christi and the Nueces and Coastal Bend Region could involve the development of a desalination facility in Corpus Christi in exchange for diversion of firm yield from the Choke Canyon Reservoir/Lake Corpus Christi (CCR/LCC) System to a water treatment plant at the major municipal demand center of the South Central Texas Region. This water management strategy compares the costs of a desalination facility drawing seawater from Laguna Madre for treatment and delivery to Corpus Christi and associated facilities to deliver water from CCR to Region L with the cost of a desalination facility drawing seawater from San Antonio Bay for treatment and delivery to Bexar County.

Desalination of the Gulf of Mexico is a potential source of water supplies for municipal and industrial uses. Cost savings may be realized from co-siting a seawater desalination facility with a power plant utilizing once-through cooling water. Therefore, the desalination facility in Corpus Christi for this water management strategy is co-sited with Barney M. Davis Power Station near Laguna Madre, Oso Bay, and Corpus Christi Bay. A cooperative water management strategy producing desalinated water at a flow of 25 MGD (28,004 acft/yr) is evaluated.

Figure 4C.23-1 shows the location of the desalination facility in Corpus Christi and the major facilities needed to deliver raw water from Choke Canyon Reservoir to a water treatment plant in the South Central Texas Region. This portion of the project includes an intake pump station at Choke Canyon Reservoir, intermediate transmission pump station(s), and a 63-mile transmission pipeline.

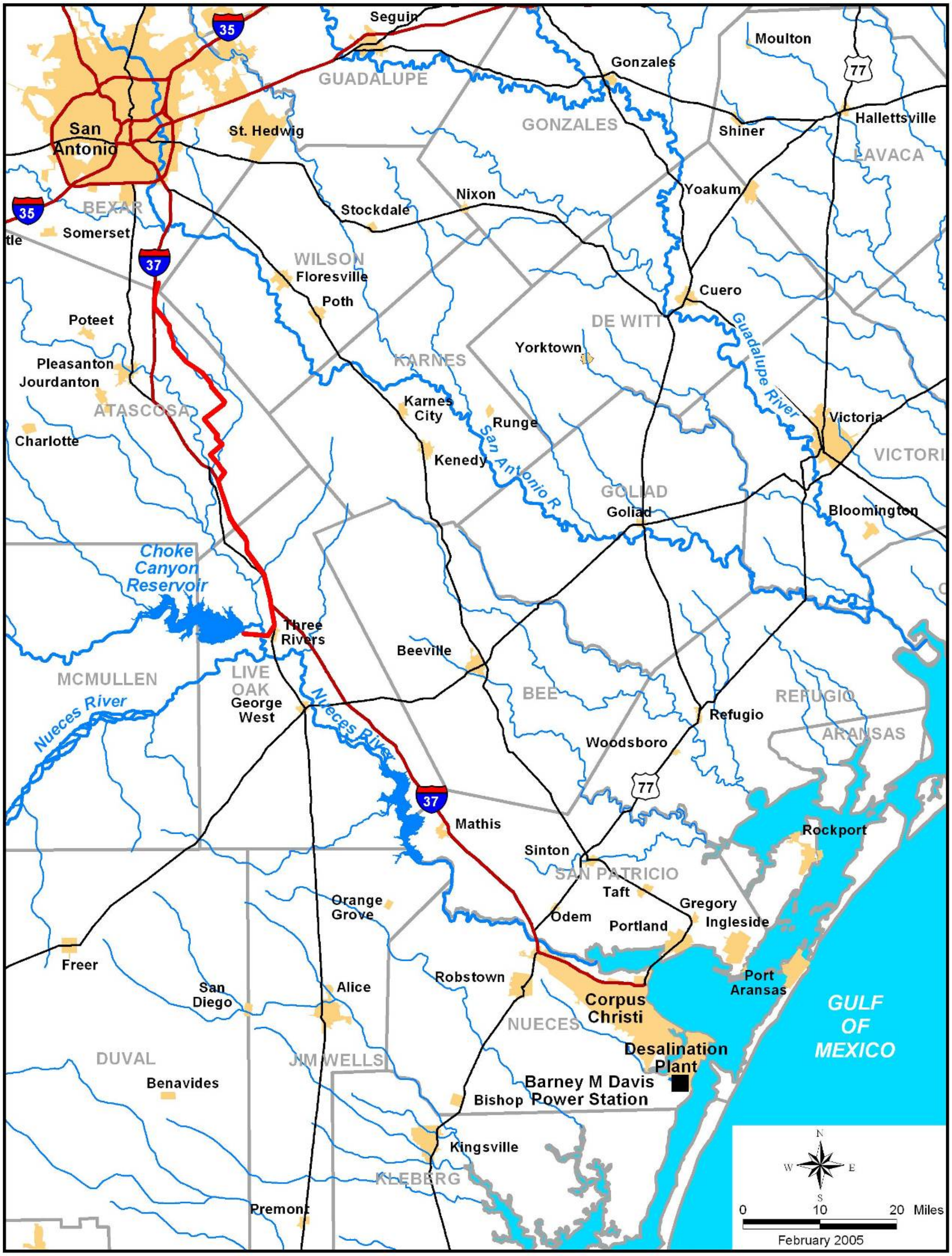


Figure 4C.23-1. Inter-regional Seawater Desalination

4C.23.2 Available Yield

Seawater from the Gulf of Mexico is an unlimited quantity within the context of a supply for the South Central Texas Region. For the purpose of developing this strategy in which seawater from the Gulf of Mexico is desalted to develop a significant drinking water supply for Corpus Christi, it is assumed that the availability of Gulf water is unlimited and that its cost is zero prior to extraction from the source.

The firm yield from the Choke Canyon Reservoir/Lake Corpus Christi (CCR/LCC) System is 178,700 acft/yr[1]. The water for this strategy is supplied by Choke Canyon Reservoir and will not include flows available downstream in the Nueces River and in Lake Corpus Christi. The firm yield solely available from Choke Canyon Reservoir is not known, but it is anticipated that the water available from Choke Canyon Reservoir exceeds the 28,004 acft/yr required firm yield for this strategy.

4.23.3 Environmental Issues

One portion of the Inter-Regional Seawater Desalinations water management strategy diverts water from Choke Canyon Reservoir to the South Central Texas Region via a 63-mile transmission line. The pipeline route lies within the South Texas Plains vegetational area and traverses the Southern Texas Plains (about 40 percent), East Central Texas Plains (about 35 percent), and Texas Blackland Prairies (about 25 percent) ecoregions.[2,3,4] The South Texas Plains vegetation area is mainly comprised of rangeland. The vegetation associated with this area has shifted from grassland or savannah to shrubs characterized by Mesquite, Live Oak (*Quercus virginiana*), Acacia, and Post Oak. Soils in this area range from clay to sandy loams and calcareous to slightly acid.[4]

Plant and animal species listed by USFWS, and TPWD that may be within the vicinity of the pipeline route are listed in Table 4.3-1. The Wildlife Science Research and Diversity Maps, maintained by TPWD indicate several species of rare plants in the vicinity of the pipeline route from Choke Canyon Reservoir to San Antonio: Sandhill Woolywhite (*Hymenopappus carrizoanus*), Parks' Jointweed (*Polygonella parksii*), Elmendorf's Onion (*Allium elmendorfii*),

[1] Texas Commission on Water Quality / HDR Engineering, Inc., "Nueces River Water Availability Model".
[2] Omernik, James M., "Ecoregions of the Conterminous United States," Annals of the Association of American Geographers, 77(1): pp. 118-125, 1987.
[3] Blair, W.F., "The Biotic Provinces of Texas," Texas Journal of Science 2(1): pp. 93-117, 1950.
[4] Gould, F.W., "The Grasses of Texas," Texas A&M University Press, College Station, Texas, 1975.

and South Texas Rushpea (*Caesalpinia phyllanthoides*). In addition, the Texas garter snake, another rare species is also found in this area.

The golden-cheeked warbler (*Dendroica chrysoparia*) and black-capped vireo (*Vireo atricapillus*), both endangered species, nest in Bexar County. From March through August, the golden-cheeked warbler inhabits the mature Oak-Ashe Juniper woods of Bexar County. It requires strips of Ashe Juniper bark for nest material. The black-capped vireo nests in dense underbrush in semi-open woodlands having distinct upper and lower stories. The northern aplomado falcon is another endangered bird found within the project region. This species prefers open county, especially savanna and open woodland. A potential migrant, the endangered whooping crane could also be found within this area.

Several federal and state protected birds (white-faced ibis, white-tailed hawk, interior least tern, and zone-tailed hawk) have been reported to occur in counties where pipeline routes have been proposed for this project (Table 4C.23-1 shows a description of status and preferred habitat). The interior least tern also inhabits McMullen and Live Oak Counties that are traversed by the proposed route from Choke Canyon Reservoir to San Antonio. The zone-tailed hawk (*Buteo albonotatus*) has been sited in Bexar County and prefers arid, open county that has deciduous or pine-oak woodland.

Pipeline construction is expected to require field surveys for protected species, vegetation, habitats, and cultural resources during right-of-way selection to avoid or minimize impacts. When potential protected species habitat or other significant resources cannot be avoided, additional studies would have to be conducted to evaluate habitat use or eligibility for inclusion in the National Register for Historic Places, respectively. Wetland impacts, primarily pipeline stream crossings, can be minimized by right-of-way selection and appropriate construction methods, including erosion controls and vegetation procedures. Compensation for net losses of wetlands would be required where impacts are unavoidable.

Table 4C.23-1.
Important Species* Having Habitat or Known to Occur in Counties Potentially Affected by Inter-regional Desalination

Common Name	Scientific Name	Impact Value	Multiplier Based on Status	Adjusted Impact	Summary of Habitat Preference	Listing Entity		Potential Occurrence in County
						USFWS1	TPWD1	
American Eel	*Anguilla rostrata*	1	1	1	Aquatic habitats with access to ocean.			Resident
American Peregrine Falcon	*Falco peregrinus anatum*	0	3	0	Open country; cliffs	DL	E	Nesting/Migrant
Arctic Peregrine Falcon	*Falco peregrinus tundrius*	0	2	0	Open country; cliffs	DL	T	Nesting/Migrant
Atlantic Hawksbill Sea Turtle	*Eretmochelys imbricata*	1	3	3	Gulf and bay system.	LE	E	Migrrant
Attwater's Greater Prairie-chicken	*Tympanuchus cupido attwateri*	2	3	6	Open prairies	LE	E	Resident
Audubon's Oriole	*Icterus graduacauda audubonnii*	1	1	1	South Texas; Mesquite and evergreen woodlands			Nesting/Migrant
Bald Eagle	*Haliaeetus leucocephalus*	2	2	4	Large bodies of water with nearby resting sites	T	T	Nesting/Migrant
Big Free-tailed Bat	*Nyctinomops macrotis*	0	1	0	Prefers to roost in crevices and cracks in canyon walls.			Resident
Big Red Sage	*Salvia penstemonoides*	2	1	2	Endemic; Creekbeds and seepage slopes of limestone canyons			Resident
Black Bear	*Ursus amricanus*	0	2	2	Bottomland hardwoods.	T/SA; NL	T	

Table 4C.23-1 continued

Black-capped Vireo	*Vireo atricapillus*	1	3	3	Semi-open broad-leaved shrublands	LE	E	Nesting/Migrant
Black-spotted Newt	*Notophthalmus meridionalis*	1	2	2	Wet or temporally wet arroyos, canals, ditches, shallow depressions; aestivates underground during dry periods		T	Resident
Bracted Twistflower	*Streptanthus bracteatus*	1	1	1	Endemic; Shallow clay soils over limestone; rocky slopes			Resident
Braken Bat Cave Meshweaver	*Cicurina venii*	0	3	0	Small eyeless spider, in Karst features in western Bexar County.	LE		Resident
Brown Pelican	*Pelecanus occidentalis*	0	3	0	Largely coastal and near shore areas.	LE	E	Resident
Cagle's Map Turtle	*Graptemys caglei*	1	2	2	Endemic, Guadalupe River System.	C1	T	Resident
Cave Myotis Bat	*Myotis velifer*	0	1	0	Colonial & cave dwelling; hibernates in limestone caves of Edwards Plateau			Resident
Coastal Gay-feather	*Liatris bracteata*	2	1	2	Black clay soils of midgrass grasslands on coastal prairie remnants			Resident
Cokendolpher Cave Harvestman	*Texella cokendolpheri*	0	3	0	Small eyeless harvestman, karst features in north-central Bexar county.	LE		Resident
Comal Blind Salamander	*Eurycea tridentifera*	0	2	0	Endemic; Semi-troglobitic; Springs and waters of caves		T	Resident
Crown Coreopsis	*Coreopsis nuecensis*	0	1	0				Resident
Correll's False Dragon-Head	*Physostegia correllii*	0	1	0	Wet soils			Resident
Drummond Rushpea	*Caesalpinia drummondi*	0	1	0				Resident

Table 4C.23-1 continued

Edwards Plateau Spring Salamander	*Eurycea sp. 7*	0	1	0	Troglobitic; Edwards Plateau			Resident
Elmendorf's Onion	*Allium elmendorfii*	1	1	1	Endemic; deep sands derived from Queen City and similar Eocene formations			Resident
Eskimo Curlew	*Numenius borealis*	1	3	3	Grasslands, pastures, plowed fields.	LE	E	Resident
Golden-Cheeked Warbler	*Dendroica chrysoparia*	1	3	3	Woodlands with oaks and old juniper	LE	E	Nesting/Migrant
Government Canyon Bat Cave Meshweaver	*Cicurina vespera*	0	3	0	Small, eyeless spider, karst features in northwestern Bexar County.	LE		Resident
Government Canyon Bat Cave Spider	*Neoleptoneta microps*	0	3	0	Small eyeless spider, karst features in northwestern Bexar County.	LE		Resident
Green Sea Turtle	*Chelonia mydas*	1	2	2	Gulf and bay system.	LE	T	Migrant
Ground Beetle #1	*Rhadine exilis*	0	3	0	Eyeless beetle, karst features in northern Bexar County.	LE		Resident
Ground Beetle #2	*Rhadine infernalis*	0	3	0	Small eyeless ground beetle; karst features in northern and western Bexar County.	LE		Resident
Guadalupe Bass	*Micropterus treculi*	2	1	2	Streams of eastern Edwards Plateau			Resident
Gulf Saltmarsh Snake	*Drymarchon corais*	0	1	0	Woodlands of south Texas.		T	Resident
Helotes Mold Beetle	*Batrisodes venyivi*	0	3	0	Small eyeless modle beetle; karst features in northwestern Bexar County.	LE		Resident
Henslow's Sparrow	*Ammodramus henslowii*	1	1	1	Weedy fields or cut over areas; bare ground for running and walking			Nesting/Migrant

Table 4C.23-1 continued

Indigo Snake	*Drymarchon corais*	1	2	2	Woodlands of south Texas.		T	Resident
Interior Least Tern	*Sterna antillarum athalassos*	1	3	3	Inland river sandbars for nesting and shallow waters for foraging	LE	E	Nesting/Migrant
Jaguarundi	*Felis yagouaroundi*	0	3	0	South Texas thick brushlands, favors areas near water	LE	E	Resident
Keeled Earless Lizard	*Holbrookia propinqua*	1	1	1	Sandy areas.			Resident
Kemp's Ridley Sea Turtle	*Lepidochelys kempii*	1	3	3	Gulf and bay system.	LE	E	Migrant
Leatherback Sea Turtle	*Lepidochelys kempii*	1	3	3	Gulf and bay system.	LE	E	Migrant
Lila de los Llanos	*Echeandia chandleri*	1	1	1	Grasslands and openings in subtropical woodlands.			Resident
Manfreda Giant-skipper	*Stallingsia maculosus*	1	1	1	Small insect.			Resident
Madla Cave Meshweaver	*Cicurina madla*	0	3	0	Small eyeless spider, karst features in northern Bexar County.	LE		Resident
Maritime Pocket Gopher	*Geomys personatus maritimus*	0	1	0	Fossorial, in deep sandy soils			Resident
Mexican Blackhead Snake	*Tantilla atriceps*	0	1	0	Southern Texas, shrubland savanna.			Resident
Mexican Mud-plantain	*Heteranthera mexicana*	0	1	0	Aquatic in ditches and ponds			Resident
Mexican Treefrog	*Smilisca baudinii*	1	2	2	Subtropical woodlands		T	Resident
Mimic Cavesnail	*Phreatodrobia imitata*	0	1	0	Subaquatic; wells in Edwards Aquifer			Resident
Mountain Plover	*Charadrius montanus*	1	1	1	Shortgrass plains and fields, sandy deserts, plowed fields			Nesting/Migrant

Table 4C.23-1 continued

Northern Aplomado Falcon	*Falco femoralis septentrionalis*	0	3	0	Open country, especially savanna and open woodland.	LE	E	Resident
Nueces Crayfish	*Procambarus nueces*	0	1	0	Known only from one tributary to the Nueces River.			Resident
Ocelot	*Leopardus pardalis*	1	3	3	Dense chaparral thickets.	LE	E	Resident
Opossum Pipefish	*Microphis brachyurus*	1	2	2	Brooding adults found in fresh or low salinity waters.		T	Resident
Parks' Jointweed	*Polygonella parksii*	1	1	1	South Texas Plains; subherbaceous annual in deep loose sands, spring-summer			Resident
Piping Plover	*Charadrius melodus*	0	2	0	Wintering migrant on coast.	LT	T	Migrant
Plains Gumweed	*Grindelia oolepsis*	2	1	2	Early successional patches in coastal prairies on heavy clay soils			Resident
Plains Spotted Skunk	*Spilogale putorius interrupta*	1	1	1	Catholic; Wooded, brushy areas and tallgrass prairies			Resident
Red Wolf (extirpated)	*Canis rufus*	0	3	0	Woods, prairies, river bottom forests	LE	E	
Reddish Egret	*Egretta rufescens*	0	2	0	Resident of brackish marshes.		T	Resident
Reticulate Collared Lizard	*Crotaphytus reticulatus*	1	2	2	Endemic grass prairies of South Texas Plains; usually thornbush, mesquite-blackbrush		T	Resident
Robber Baron Cave Meshweaver	*Cicurina baronia*	0	3	0	Small, eyeless spider, karst features in north-central Bexar County.	LE		Resident

Table 4C.23-1 continued

Sandhill Woolywhite	*Hymenopappus carrizoanus*	1	1	1	Endemic; Open areas in deep sands derived from Carrizo and similar Eocene formations			Resident
Sennett's Hooded Oriole	*Icterus cucullatus sennetti*	1	1	1	Builds nests of Spanish moss.			Resident
Sheep Frog	*Hypopachus variolosus*	1	2	2	Predominately grassland and savannas; moist sites in arid regions.		T	Resident
Silvery Wild Mercury	*Argythamnia argyralia*	0	1	0				Resident
Slender rushpea	*Hoffmannseggia tenella*	0	3	0	Endemic, Grasslands on heavy clay soils.	LE	E	Resident
Snowy Plover	*Charadrius alexandrus*	0	1	0	Beaches, flats, streamsides			Winter resident
Sooty Tern	*Sterna fuscata*	1	2	2	Flies or hovers over water.		T	Resident
South Texas ambrosia	*Ambrosia cheiranthifolia*	0	3	0	Open prairies and shrublands.	LE	E	Resident
South Texas Rushpea	*Caesalpinia phyllanthoides*	1	1	1				Resident
South Texas Siren (Large form)	*Siren sp. 1*	1	2	2			T	Resident
Southern Yellow Bat	*Lasiurus ega*	0	2	0	Associated with palm trees in Brownsville.		T	Resident
Spot-tailed Earless Lizard	*Holbrookia lacerata*	1	1	1	Oak-juniper woodlands and mesquite-prickly pear			Resident
Texas Botteri's Sparrow	*Aimophila botterii texana*	0	2	0	Coastal lowlands and prairies.		T	Resident
Texas Diamondback Terrapin	*Malaclemys terrapin litoralis*	0	2	0	Bays and coastal marshes			Resident
Texas Garter Snake	*Thamnophis sirtalis annectens*	1	1	1	Varied, especially wet areas; bottomlands and pastures			Resident
Texas Horned Lizard	*Phrynosoma cornutum*	1	2	2	aried, sparsely vegetated uplands		T	Resident

Table 4C.23-1 continued

Texas Salamander	*Eurycea neotenes*	0	1	0	Endemic, in springs, seeps and caves.			Resident
Texas Scarlet Snake	*Cemophora coccinea lineri*	1	2	2	Mixed hardwood scrub on sandy soils.		T	Resident
Texas Tortoise	*Gopherus berlandieri*	1	2	2	Open brush with grass understory; open grass and bare ground avoided; occupies shallow depressions at base of bush or cactus, underground burrows, under objects; active March-Nov		T	Resident
Texas Willkommia	*Wilkommia texana*	0	1	0				Resident
Texas Windmill-grass	*Chloris texensis*	0	1	0	Endemic, sandy to sandy loam soils.			Resident
Threeflower Broomweed	*Thurovia triflora*	1	1	1	Black clay soils of remnant coastal prairie grasslands			Resident
Timber/Canebrake Rattlesnake	*Crotalus horridus*	1	2	2	Bottomland hardwoods		T	Resident
Toothless Blindcat	*Trogloglanis pattersoni*	0	2	0	Troglobitic; San Antonio pool of the Edwards Aquifer		T	Resident
Velvet Euphorbia	*Euphorbia innocua*	0	1	0				Resident
Welder Machaeranthera	*Psilactis heterocarpa*	2	1	2	Mesquite-huisache woodlands, shrub-invaded grasslands in clay and silt soils			Resident
West Indian Manatee	*Trichechus manatus*	0	3	0	Summer irregular transient. Shallow coastal waters.	LE	E	Migrant

Table 4C.23-1 continued

White-faced Ibis	*Plegadis chihi*	0	3	0	Varied, prefers freshwater marshes, sloughs and irrigated rice fields; Nests in low trees		T	Nesting/Migrant
White-tailed Hawk	*Buteo albicaudatus*	1	2	2	Prairies, mesquite and oak savannahs, scrub-live oak, cordgrass flats		T	Nesting/Migrant
Widemouth Blindcat	*Satan eurystomus*	0	2	0	Troglobitic; San Antonio pool of Edwards Aquifer		T	Resident
Whooping Crane	*Grus americana*	0	3	0	Potential migrant	LE	E	Migrant
White-tailed Hawk	*Buteo albicaudatus*	1	2	2	Prairies, mesquite and oak savannahs, scrub-live oak, cordgrass flats		T	Nesting/Migrant
Widemouth Blindcat	*Satan eurystomus*	0	2	0	Troglobitic; San Antonio pool of Edwards Aquifer		T	Resident
Whooping Crane	*Grus americana*	0	3	0	Potential migrant	LE	E	Migrant
Wood Stork	*Buteo americana*	0	2	0	Prairie ponds, flooded pastures or fields; shallow standing water		T	Nesting/Migrant
Zone-tailed Hawk	*Buteo albonotatus*	1	2	2	Arid, open country including deciduous or pine-oak woodland; nests in various habitats and sites		T	Nesting/Migrant

[1] Texas Parks and Wildlife Department (TPWD), Unpublished 2005, March 2005, Data and Map Files of the Wildlife Science Research and Diversity Division maintained by TPWD, Austin, Texas.

- LE/LT=Federally Listed Endangered/Threatened
- E/SA, T/SA=Federally Listed Endangered/Threatened by Similarity of Appearance
- C1=Federal Candidate for Listing
- DL, PDL=Federally Delisted/Proposed for Delisting
- NL=not Federally Listed
- E, T=State Listed Endangered/Threatened
- PE, PT=Federally Proposed Endangered/ Threatened
- Blank = Rare, but no regulatory listing status

Estuaries are marine environments maintained in a brackish state by the inflow of freshwater from rivers and streams. They serve as critical habitat and spawning grounds for many marine species and migratory birds. The high productivity characteristic of estuaries arises from the abundance of terrigenous nutrient input, shallow water, and the ability of a few marine species to exploit environments continually stressed by low, variable salinities, temperature extremes, and, on occasion, low dissolved oxygen concentrations. The potential environmental effects resulting from the construction of a desalination plant in the vicinity of Laguna Madre will primarily be a function of the source water intake and discharge locations, assuming the production facility location is constant. Because of the relatively small area and the disturbed character of the Barney Davis property, construction and maintenance of surface facilities are not expected to result in substantial environmental impacts.

A proposed desalination plant adjacent to the Barney M. Davis Power Station located in South Corpus Christi between the Laguna Madre and Oso Bay would divert Laguna Madre water, via the existing cooling water intake. This alternative will include an ocean outfall and pipeline that would discharge the concentrate back into the Gulf of Mexico at a salinity about twice that of the intake water (68,000 to 72,000 mg/l). Outfall structures will be located in water of sufficient depth (30 feet) and be designed to promote rapid dispersal of the concentrate to minimize the mixing zone in which salinities are significantly elevated. Extensive studies accompanying construction of the Strategic Petroleum Reserve on the Texas and Louisiana coasts are available to guide assessment of the effects of high salinity discharges.

Assuming an average construction corridor width of 30 feet, the concentrate pipeline across the Laguna Madre will result in disturbance of about 5 acres of existing seagrass beds, which will require mitigation. The crossing of Padre Island will disturb an additional 7.3 acres of upland and wetland coastal habitat, while construction of the intake and concentrate outfalls, and appurtenant pipeline, will disturb about 13.6 acres of neritic seabottom.

Cultural resources protection on public lands in Texas is afforded by the Antiquities Code of Texas (Title 9, Chapter 191, Texas Natural Resource Code of 1977), the National Historic Preservation Act (Pl96-515), and the Archeological and Historic Preservation Act (PL93-291). Based on the review of available records housed at the Texas Archeological Research Laboratory in Austin, thirty-eight cultural resource sites appear to occur within the area pertinent to the Inter-Regional Seawater Desalination water management strategy. Table 4C.23-2 lists archeological sites within a one-mile corridor of the proposed project area. Considering that the owner or controller of the project will likely be a political subdivision of the State of Texas (i.e. river authority, municipality, county, etc.), they will be required to coordinate with the Texas Historical Commission regarding if the project will affect waters of the United States or wetlands, the project sponsor will also be required to coordinate with the U.S. Army Corps of Engineers regarding impacts to cultural resources.

Table 4C.23-2.
Previously Recorded Sites within One-mile Distance from Inter-Regional Seawater Desalination.

Sites	41AT16	41LK64	41SP6
	41AT70	41LK79	41SP17
	41AT71	41LK83	41SP86
	41AT72	41LK84	41SP157
	41AT195	41LK113	41SP159
	41LK1	41LK114	41SP160
	41LK16	41LK115	41SP161
	41LK28	41LK116	41SP162
	41LK29	41LK255	41SP164
	41LK31	41LK306	41SP165
	41LK43	41LK308	41SP187
	41LK46	41NU191	
	41LK57	41SP1	

4C.23.4 Engineering and Costing

Tables 4C.23-3 and 4C.23-4 summarize the costs associated with implementing Inter-Regional Seawater Desalination. Table 4C.23-3 shows the cost estimate for delivering 28,004 acft/yr of firm yield from Choke Canyon Reservoir to the major demand center of the South Central Texas Region. The costs include an intake and pump station at Choke Canyon Reservoir, 63 mile transmission pipeline, one booster pump station, treatment at a regional water treatment plant in south Bexar County, and distribution system integration.

Table 4C.23-2.
Cost Estimate Summary for
Delivery of Choke Canyon Reservoir Water for Inter-Regional Desalination
(Second Quarter 2002 Prices)

Item	*Estimated Costs*
Capital Costs	
Intake and Pump Station	$6,716,000
Transmission Pipeline (63 miles)	$54,166,000
Transmission Pump Station(s)	$5,294,000
Water Treatment Plant	$25,257,000
Integration	$33,175,000
Total Capital Cost	**$124,608,000**
Engineering, Legal Costs and Contingencies	$40,904,000
Environmental & Archaeology Studies and Mitigation	$1,590,000
Land Acquisition and Surveying (316 acres)	$2,943,000
Interest During Construction (2 years)	$13,604,000
Total Project Cost	**$183,649,000**
Debt Service (6 percent, 30 years)	$13,342,000
Operation and Maintenance	
Intake, Pipeline, Pump Station	$1,163,000
Water Treatment Plant	$2,266,000
Pumping Energy Costs (@ 0.06 $/kW-hr)	$2,118,000
Total Annual Cost	**$18,889,000**
Available Project Yield (acft/yr)	28,004
Annual Cost of Water ($ per acft)	$675
Annual Cost of Water ($ per 1,000 gallons)	$2.07

Seawater desalination costs for Corpus Christi were reported in a recently completed study by TWDB[5]. The estimated seawater desalination facility is located next to the Barney M. Davis Power Station between Laguna Madre and Oso Bay in south Corpus Christi. The additional annual cost, above currently planned costs for Corpus Christi, to build and operate a 28,004 acft/yr (25 MGD) seawater desalination water supply was estimated to be $29,466,000 ($1,052 per acre/ft, $3.23 per 1000 gallons). The total cost to Corpus Christi includes “other costs” that are in addition to the capital and O&M costs of the desalinated water supply. These “other costs” are primarily due to the proposed implementation schedule in the referenced desalination study which sets the date of desalinated water delivery sooner than demand and market forces would dictate. An example of such “other costs” is the debt on existing facilities,

[5] Texas Water Development Board, “The Future of Desalination in Texas, Volume I, Biennial Report on Seawater Desalination,” December 2004.

which may be redundant once the seawater desalination facilities begin providing water. The cost model utilized to determine the total project costs to Corpus Christi was based on delivery of desalinated seawater in the year 2010. The impact of "other costs" may be decreased if the schedule for implementation of the Corpus Christi desalination project is moved back to a later date.

Table 4C.23-4 summarizes the costs for the Inter-Regional Seawater Desalination water management strategy consisting of a seawater desalination water supply to Corpus Christi in exchange for firm yield from the Choke Canyon Reservoir/Lake Corpus Christi (CCR/LCC) System.

Table 4C.23-4.
Cost Estimate Summary for 25 MGD (28,004 acft/yr) Water Supply Including Both Components of Inter-regional Desalination

Item	***Estimated Costs***
Annual Costs	
Choke Canyon Reservoir Water Supply	$18,889,000
Corpus Christi Capital and O&M for Seawater Desalination	22,885,000
Corpus Christi "Other Costs" for Debt on Existing Facilities	$6,581,000
Total Annual Costs	$48,355,000
Available Project Yield (acft/yr)	28,004
Annual Cost of Water ($ per acft)	$1,727
Annual Cost of Water ($ per 1,000 gallons)	$5.30

Table 4C.23-5 shows a comparison of the costs of a desalination facility drawing seawater from San Antonio Bay for treatment and delivery to Bexar County versus the costs of the Inter-Regional Seawater Desalination management strategy.

Table 4C.23-5.
Cost Estimate Comparison between
Inter-Regional Seawater Desalination
and Seawater Desalination at San Antonio Bay

Item	*Inter-Regional Seawater Desalination*	*Seawater Desalination at San Antonio Bay*
Total Project Cost	**$183,649,000**	**$404,482,000**
Annual Costs		
Debt Service (6 percent, 30 years)	$13,342,000	$29,385,000
Operation and Maintenance	$5,547,000	$20,090,000
Corpus Christi Capital and O&M for Seawater Desalination	$22,885,000	$0
Corpus Christi "Other Costs" for Debt on Existing Facilities	$6,581,000	$0
Total Annual Cost	**$48,355,000**	**$49,475,000**
Available Project Yield (acft/yr)	28,004	28,004
Annual Cost of Water ($ per acft)	$1,727	$1,767
Annual Cost of Water ($ per 1,000 gallons)	$5.30	$5.42

The difference between the annual cost of water estimated for Inter-Regional Seawater Desalination and Seawater Desalination at San Antonio Bay is $41 per acft ($0.12). The majority of the Inter-Regional Seawater Desalination annual cost is to implement a seawater desalination supply for Corpus Christi.

4C.23.5 Implementation Issues

Implementation of this water management strategy requires overcoming several financial, environmental, and technological impediments. The City of Corpus Christi and the Nueces and Coastal Bend Region must be willing to develop a cooperative water supply with the South Central Texas Region. The annual cost of water is likely to be a somewhat serious limitation. The subsidy required for the City of Corpus Christi to develop a seawater desalination water supply is the majority of the annual cost of water. The cost estimates show that a separate seawater desalination water supply from San Antonio Bay is competitive with the cooperative seawater supply despite the considerable transmission costs due to transferring water from the coast to the municipal demand center of the South Central Texas Region.

There are several environmental issues that must be considered. The first is the location of the intake and concentrate discharge in Laguna Madre Bay or the open Gulf. Disposal of the desalination process concentrate would have to occur at a location and in a manner that does not disrupt plant or animal life in the Bay or in the Gulf. A further complication is the permitting of a 63-mile pipeline across rivers, highways, and private rural and urban property.

Technological issues include: (1) confirming that desalination as proposed with membranes is the appropriate technology; (2) confirming that blending desalted seawater with the other water sources in the municipal demand distribution system can be successfully accomplished; and (3) obtaining an adequate source of electric power to drive the desalination process using membranes. The cost of seawater desalination for Corpus Christi is based on an extensive study recently evaluated by the TWDB. The Corpus Christi desalination costs are not specific for a water management strategy involving regional cooperation and may need to be revised based on a differing implementation schedule and other factors that may affect the annual cost of a seawater desalination supply to Corpus Christi.

Substantial verification of desalination technology would need to be accomplished prior to building this project. Blending differing treated waters is critical for the well being of the customers and the distribution system. The characteristics of the desalted water are likely to be dramatically different from other drinking water in Corpus Christi. Considerable investigation would be needed to determine if additional conditioning of the desalinated seawater would be required to make the new water source compatible with existing distribution systems. Conditioning of the desalinated seawater may include addition of alkalinity and hardness to bring the corrosion chemistry closer to other existing water sources.

Finally, in spite of recent improvements in membrane technology, desalting seawater will require large amounts of electric power. Normally, this need is met by locating desalination plants near power plants. Future costs of electric power, however, are highly uncertain and represent a very significant component of annual operating costs for this strategy.

Requirements Specific to Water Rights

1. It will be necessary to obtain these permits:
   a. TCEQ Water Right permits and amendments.
   c. GLO Sand and Gravel Removal permits.
   d. GLO Easement for use of state-owned land.

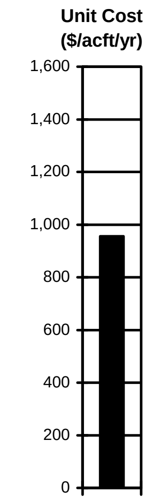
   e. Coastal Coordination Council review.
   f. TPWD Sand, Gravel, and Marl permit.
2. Permitting, at a minimum, will require these studies:
   a. Assessment of changes in instream flows and freshwater inflows to bays and estuaries.
   b. Habitat mitigation plan.
   c. Environmental studies.
   d. Cultural resources.
3. Other Considerations:
   a. Water compatibility testing, including biological and chemical characteristics will need to be performed.
   b. Willingness of interests in the South Central Texas Region and the Coastal Bend Region to develop a joint water supply.
   c. Negotiation of agreement(s) between the City of Corpus Christi, Nueces River Authority, SAWS, and the U.S. Bureau of Reclamation.

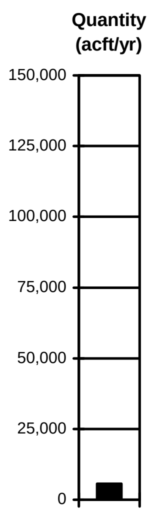
Requirements Specific to Pipelines

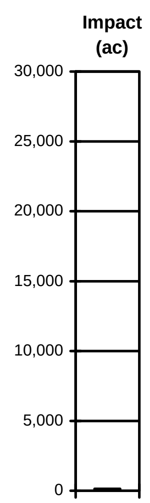
1. Necessary permits:
   a. USACE Sections 10 and 404 dredge and fill permits for stream crossings.
   b. GLO Sand and Gravel Removal permits.
   c. TPWD Sand, Gravel, and Marl permit for river crossings.
2. Right-of-way and easement acquisition.
3. Crossings:
   a. Highways and railroads
   b. Creeks and rivers
   c. Other utilities

(This page intentionally left blank.)

2006 South Central Texas Regional Water Plan
Water Management Strategy Summary Sheet







Name: CRWA Dunlap Project

Description: Water management strategy includes an amendment to CRWA's existing water right at Lake Dunlap (changing the authorized diversions from 18.52 acft/yr to 5,600 acft/yr) and conjunctive use of up to 5,600 acft/yr of Carrizo Aquifer groundwater with delivery to the CRWA Wagner Booster Station in Guadalupe County. Facilities include surface water pump station and water treatment plant expansions at Lake Dunlap, shared groundwater facilities including 18-500 gpm wells in Gonzales & Guadalupe Counties, collection system, groundwater treatment plant, transmission pump station, and a 30-mile 30-inch transmission pipeline. Shared facilities serve both the CRWA Dunlap Project and the Wells Ranch Project and have a total annual production capacity of 9,000 acft/yr. Facilities sized for delivery on a peak month basis for municipal supply. (For the purposes of modeling anticipated drawdown, this project was considered along with the Wells Ranch Project.)

***Decade Needed*:** 2000 – 2010

Cost, Quantity of Water, and Land Impacted

Unit Cost of Water:	**$956**	**$/acft/yr**	**Treated Water Delivered**
Quantity of Water:	**5,600**	**acft/yr**	**Reliability = Firm**
Land Impacted:	**131**	**acres**	

Additional Considerations per Regional Water Planning Guidelines

Environmental Factors:

Threatened species include the Texas Horned Lizard, the Texas Tortoise, and the Cagle's Map Turtle. Groundwater pumpage could affect springflows and base streamflows.

Impacts on Water Resources:

Reductions in streamflows in the Guadalupe River associated with the CRWA Amendment. Long-term reductions in aquifer levels.

Impacts on Agricultural & Natural Resources:

Minimal, if any.

Other Relevant Factors per SCTRWPG:

Conjunctive use of surface water and local groundwater during wet periods. During drought, nearly all supply is from groundwater. Gonzales County Underground Water Conservation District (GCUWCD) and the Guadalupe County Groundwater Conservation District have rules and management plans that need to be considered in project planning. Local GCDs have permitting authority over any export project within their jurisdiction. This project was evaluated in conformance with the existing rules of the Gonzales County UWCD. Part of the supply developed by this project exceeds the amount of available water identified in the current Gonzales County UWCD management plan. The amount of water needed by the project that exceeds the available water in the management plan cannot be implemented unless and until permits are received from the Gonzales County UWCD. This project does not cause the Gonzales UWCD management plan to be in conflict with the South Central Texas Regional Water Plan. See Public Comments and SCTRWPG Responses Developed through Facilitation for Issues 2, 5, and 6 in Section 10.2.2.3. An agreement between BMWD and Guadalupe County GCD limits pumpage from Wells Ranch in Guadalupe County to 1,400 acft/yr.

Comparison of Strategies to Meet Needs:

Limited conflicts with other recommended water strategies including SSLGC Project Expansion, Wells Ranch Project, Hays/Caldwell Carrizo Project and/or Regional Carrizo for Bexar County Supply.

Interbasin Transfer Issues:

To the extent that surface water is exported to the San Antonio River Basin, this water management strategy is an Inter-basin Transfer.

Third-Party Impacts of Voluntary Transfers:

Mitigation (i.e., lowering of pumps, drilling of new wells, etc.) is required by GCDs for affected third parties.

Regional Efficiency:

New supply proximate to water user groups with projected needs.

Water Quality Considerations:

Carrizo-Wilcox water may contain high iron and manganese concentrations.

(This page intentionally left blank.)

4C.24 CRWA Dunlap Project

4C.24.1 Description of Water Management Strategy

The CRWA Dunlap Project is conceived as a conjunctive use project that would utilize surface water from the Guadalupe River when flows are available, and supplement this supply with groundwater from the Wells Ranch well field in Guadalupe and Gonzales Counties during times of drought and low stream flows when senior water rights utilize all available water in the Guadalupe. For the surface water supply, an existing pump station and water management strategy (WTP) on the Guadalupe at Lake Dunlap would be expanded to accommodate the increased capacity, and treated water would be delivered to CRWA customers via the existing Mid-Cities pipeline. For the groundwater supply, CRWA would share common infrastructure with Bexar Metropolitan Water District (BMWD), developed for the Wells Ranch Carrizo Project (see details in Section 4C.16). Groundwater would be extracted from the Wells Ranch well field, treated, and conveyed via transmission pipeline to CRWA's Wagner Booster Station in Guadalupe County, where it could be delivered to existing customers via the CRWA Mid-Cities pipeline. This water management strategy is planned to supply up to 5,600 acft/yr of water to CRWA.

4C.24.2 Water Supply

4C.24.2.1 Surface Water Availability

CRWA proposes to amend its existing water right (Certificate of Adjudication #18-3834) on the Guadalupe River to increase authorized diversions from 18.52 acft/yr to 5,600 acft/yr. The Guadalupe-San Antonio River Basin Water Availability Model (GSAWAM, as modified for regional water planning purposes) was used to quantify water available for diversion under the CRWA water right and potential amendment. Hydrologic simulations and calculations were performed subject to the General Assumptions for Applications of Hydrologic Models adopted by the South Central Texas Regional Water Planning Group and listed in Appendix B of Volume II.

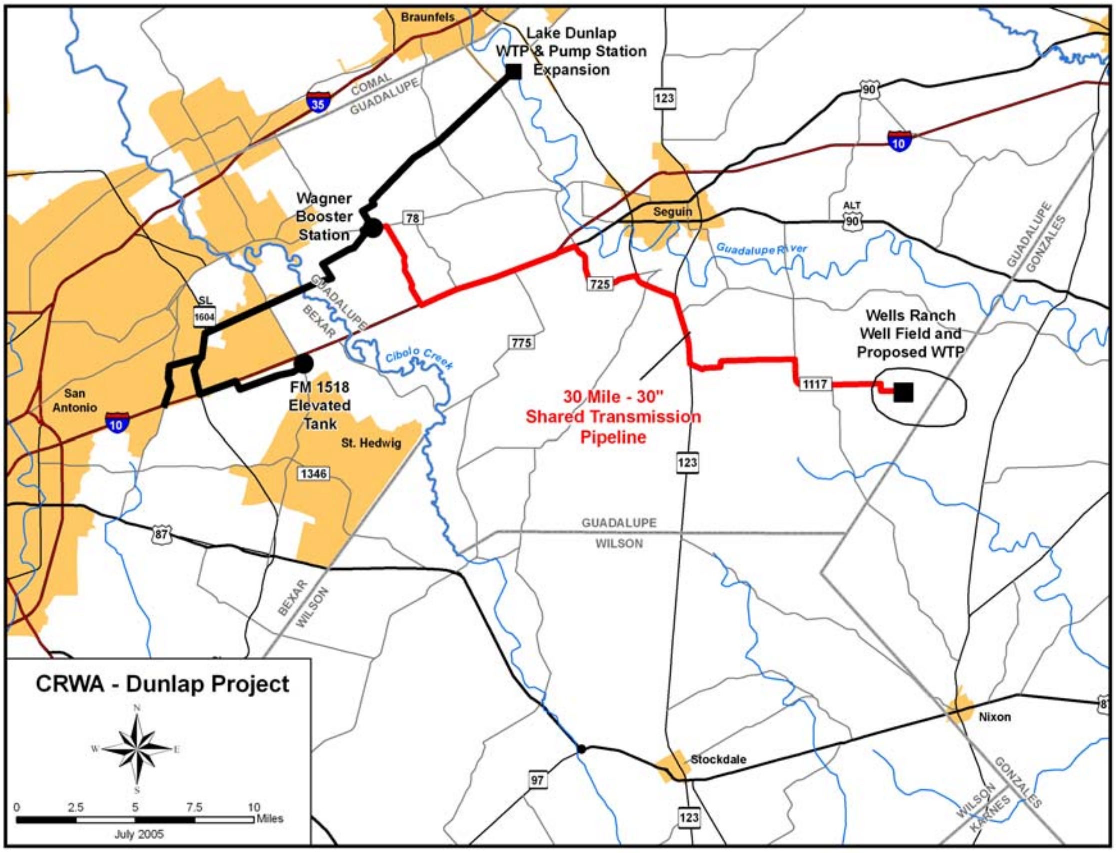


Figure 4C.24-1 CRWA Dunlap Project

The proposed amendment to Permit #18-3834 increasing authorized diversions by more than 5,581 acft/yr was modeled as the most junior water right in the Guadalupe-San Antonio Basin and was subject to senior water rights and environmental flow restrictions consistent with Consensus Criteria for Environmental Flow Needs (CCEFN). Table 4C.24-1 contains the applicable streamflow statistics to be used in the application of CCEFN at Lake Dunlap. As senior water rights for diversion of up to 1300 cfs at any time are associated with the hydropower generation facilities at Lake Dunlap and other downstream locations, application of the CCEFN has no effect on water availability.

The total surface water available to the potentially amended CRWA water right as a part of the CRWA Dunlap Project is shown in Figure 4C.24-2. In addition, Figure 4C.24-2 shows the make-up groundwater necessary from the Wells Ranch well field for a firm yield of 5,600 acft/yr. The long-term average (1934-1989) availability from the Guadalupe River under the

Table 4C.24-1.
Daily Naturalized Streamflow Statistics for Guadalupe River at Dunlap

Month	***Median Flows - Zone 1 Pass-Through Requirement (cfs)***	***25th Percentile Flows - Zone 2 Pass-Through Requirement (cfs)***
January	567.5	390.1
February	592.0	409.3
March	598.7	396.9
April	606.6	399.4
May	717.9	406.3
June	644.1	371.0*
July	507.5	371.0*
August	435.4	371.0*
September	472.8	371.0*
October	518.0	371.0*
November	515.1	371.0*
December	569.1	371.0*
Zone 3 Pass-Through Requirement (cfs)		371.0
** Zone 3 Pass-Through Requirement exceeds 25th Percentile Flow.*		

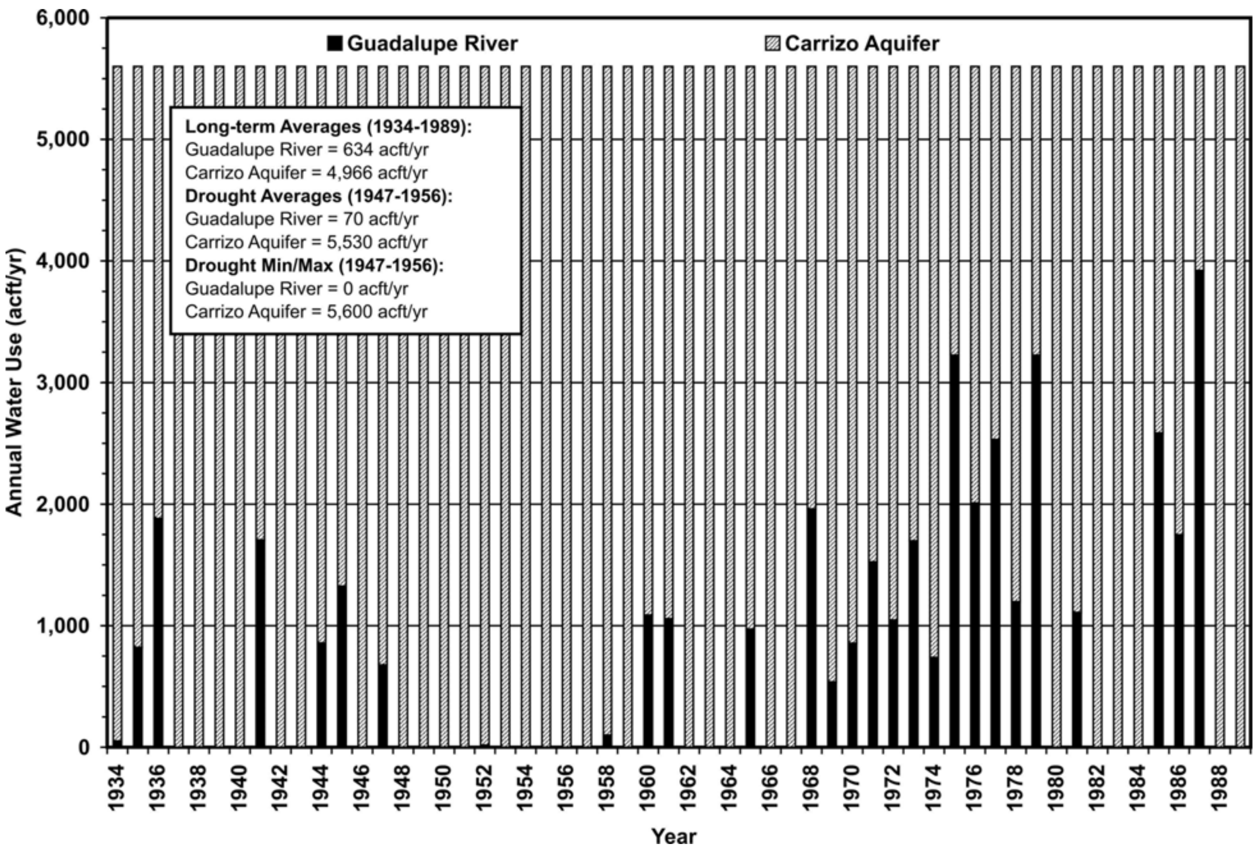


Figure 4C.24-2. CRWA Dunlap Project — Water Supply Sources

CRWA water right and the potential amendment is 634 acft/yr, while the drought average (1947-1956) availability is 70 acft/yr. The corresponding make-up water requirements on a long-term and drought average are 4,966 acft/yr and 5,530 acft/yr, respectively. In addition, in seven years of the 10-year drought period (1947-1956) no water would be available for diversion under CRWA's water right or amendment. For modeling purposes, diversions were limited to 11.4 cfs (the peak monthly diversion rate).

As surface water diversions are limited to times during which flow passing Lake Dunlap exceeds 1300 cfs and 1300 cfs is well in excess of the monthly median flow at this location, operations of this water management strategy would result in no changes in monthly median flows. Similarly, the maximum surface water diversion rate of 11.4 cfs represents less than 1 percent of 1300 cfs, so surface water diversions are expected to have no significant effects on the prevailing streamflow regimes at this point or any downstream locations along the Guadalupe River. Hence, comparison of monthly median streamflow and streamflow frequency with an without the water management strategy are not presented herein.

4C.24.2.2 Groundwater Availability

The Carrizo Aquifer in areas south and east of the source area identified for this project has proven to be very productive, with high capacity wells in the confined section of the aquifer routinely capable of producing in excess of 1,000 gpm. However the proposed well field for the Wells Ranch Project is located much closer to the outcrop and long-term production capacities are expected to be less than 1,000 gpm. Based on performance testing of existing wells, recommendations of a consultant to BMWD[1], and current permit conditions with GCUWCD, a production capacity of 500 gpm has been adopted for this technical evaluation.

On October 13, 2004, a coordination meeting was held in the City of Seguin at which the SCTRWPG solicited input from CRWA and BMWD regarding the quantity of groundwater pumpage that they were interested in seeing modeled during the water management strategy evaluation. BMWD responded that they anticipated reaching their ultimate goal of pumping 9,000 acft/year from the Wells Ranch well field by the year 2010. This is the amount that was included in predictive groundwater model simulations conducted in support of the water management strategy evaluation, and later in the cumulative effects evaluation (Sections 4C.18

[1] R.W. Harden & Associates, Wells Ranch Well Field Evaluation, November 2000.

and 7.1). Estimated pumpage associated with all Carrizo groundwater WMS projects is displayed in Figure 4C.24-3 and presented in Table 4C.24-2.

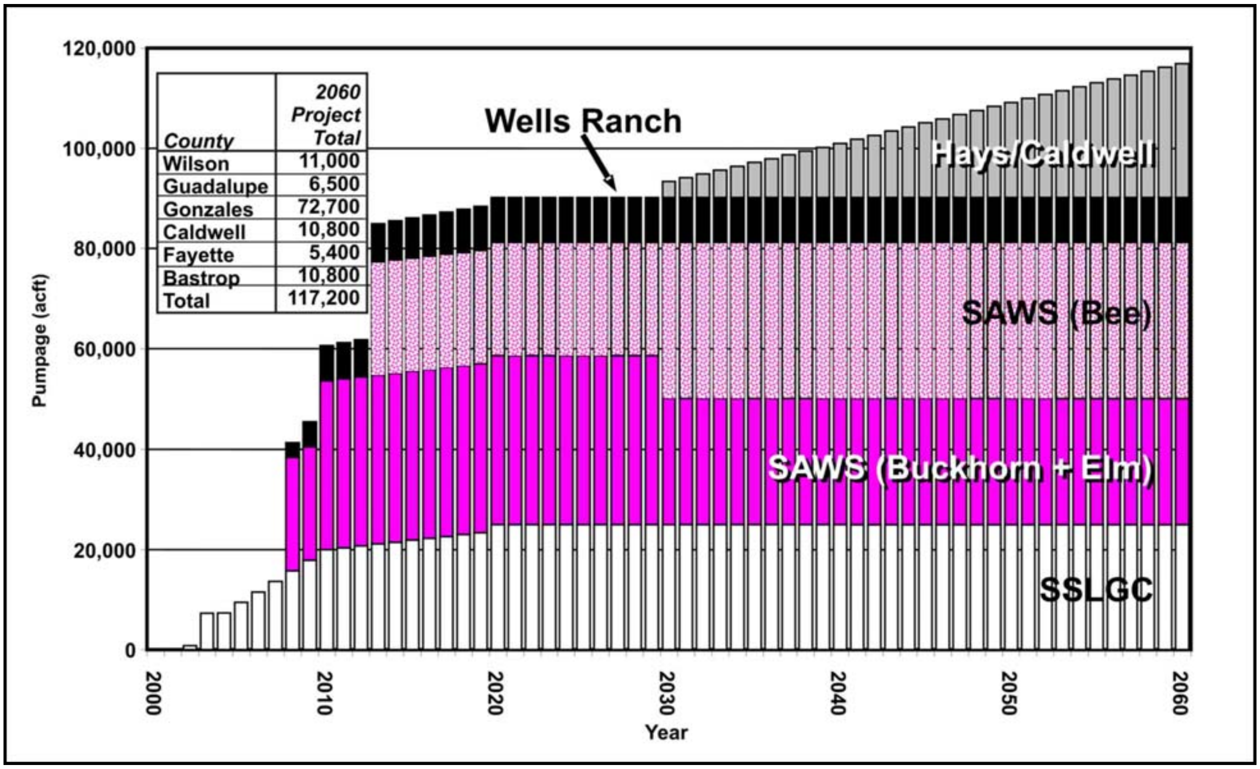


Figure 4C.24-3. Carrizo Groundwater WMS Predictive Pumpage

Table 4C.24-2.
Carrizo Groundwater WMS Predictive Pumpage

Year	*SSLGC*	*SAWS Buckhorn*	*SAWS Elm*	*SAWS Bee*	*Wells Ranch*	*Hays/ Caldwell*	*Total*
2002	796	0	0	0	0	0	796
2008	11,794	22,600	0	0	3,000	0	37,394
2010	20,000	22,600	11,000	0	7,000	0	60,600
2013	21,500	22,600	11,000	22,600	7,600	0	85,300
2020	25,000	22,600	11,000	22,600	9,000	0	90,200
2030	25,000	16,950	8,250	31,000	9,000	3,168	93,368
2040	25,000	16,950	8,250	31,000	9,000	10,757	100,957
2050	25,000	16,950	8,250	31,000	9,000	18,981	109,181
2060	25,000	16,950	8,250	31,000	9,000	27,000	117,200

With respect to the overall availability of 9,000 acft/yr of groundwater from the proposed well field, it is noted that permits for production must be obtained from the Guadalupe County Groundwater Conservation District (GCGCD) as well as the GCUWCD. A settlement agreement between BMWD and the GCGCD has been executed which stipulates that a maximum of 1,400 acft/yr may be pumped from the Wells Ranch property in Guadalupe County. It is assumed for purposes of this evaluation that permits for production of the remaining 7,600 acft/yr can be obtained from GCUWCD.

This project was evaluated in conformance with the existing rules of the GCUWCD. Part of the supply developed by this project exceeds the amount of available water identified in the current GCUWCD management plan. The amount of water needed by the project that exceeds the available water in the management plan cannot be implemented unless and until permits are received from the GCUWCD. This project does not cause the GCUWCD management plan to be in conflict with the South Central Texas Regional Water Plan.

The specific predictive simulations that were performed with this project pumpage simulated the entire 9,000 acft/yr of availability as one pumping center; no effort was made to separate simulations for the groundwater associated with the complementary BMWD Wells Ranch (3,400 acft/yr) and CRWA Dunlap Projects (up to 5,600 acft/yr). These simulations also included pumpage for the Hays/Caldwell Carrizo Project, located in Caldwell, Bastrop, Fayette, and northern Gonzales Counties (Section 4C.17). Because the Hays/Caldwell Carrizo Project is located in northern Gonzales County, and is near the outcrop, it is judged to be sufficiently distant to include in the same simulation without having a significant impact on drawdowns calculated for the Wells Ranch Project.

4C.24.2.2.1 Projected Drawdown

In order to evaluate potential drawdown associated with the Wells Ranch and CRWA Dunlap Projects, predictive groundwater modeling simulations were performed with identical pumpage represented both the South Central Carrizo System[2] (SCCS) groundwater model and

[2] HDR Engineering, Inc., "South Central Carrizo System Groundwater Model, SAWS Gonzales Carrizo Project," prepared for the San Antonio Water System, November 2004.

the Southern Carrizo-Wilcox Queen City Sparta Groundwater Availability Model[3] (SCWQSGAM). Annual Wells Ranch and CRWA Dunlap Project pumpage for these simulations was assumed to be 100 percent of the pumpage displayed in Figure 4C.24-3, with a combined maximum pumpage of 9,000 acft/yr by 2020 associated with these projects. As was done in the Regional Carrizo for Bexar County strategy evaluation (Section 4C.14) and the SSLGC Project Expansion strategy evaluation (Section 4C.15), the Wells Ranch and CRWA Dunlap Projects pumpage was added to the pumpage from previous runs, so that baseline pumpage for local supply and other project pumpage would be included in the simulations.

The resulting total combined drawdown from local baseline plus all project pumpage (SSLGC, SAWS, Wells Ranch, and Hays/Caldwell) is presented in Figures 4C.24-3 and 4C.24-4. The SCCS model calculates a maximum 10-foot drawdown contour of 120 feet at the project location in 2060. The SCWQSGAM calculates a maximum drawdown contour of 180 feet at the site.

The drawdown attributable to the Wells Ranch and CRWA Dunlap Projects was separated from drawdown due to local pumpage and other projects using the method described in Section 4C.14. Both the SCCS Model and the SCWGAM calculate a maximum drawdown of about 60 feet attributable to the Wells Ranch and CRWA Dunlap Projects (Figures 4C.24-5 and 4C.24-6).

In order to examine the change in drawdown with time associated with the projects, hydrographs were developed for near the project location in the GCUWCD network. Hydrographs were developed for observation wells sited at the cities of Nixon, Stockdale, Bebe, Smiley, and Gonzales County Monitor Well 17 near the SAWS Bee well field. Hydrographs associated with the four predictive scenarios of Local Supply Pumpage, Local Supply + SSLGC, Local Supply + SSLGC + SAWS, and Local Supply + All Projects are displayed in Section 4C.14 in Figures 4C.14-9 (SCCS) and 4C.14-10 (SCWQSGAM).

[3] Intera, with Bureau of Economic Geology and R.J. Brandes Company, "Groundwater Availability Model for the Queen City and Sparta Aquifers," prepared for the Texas Water Development Board, October 2004.

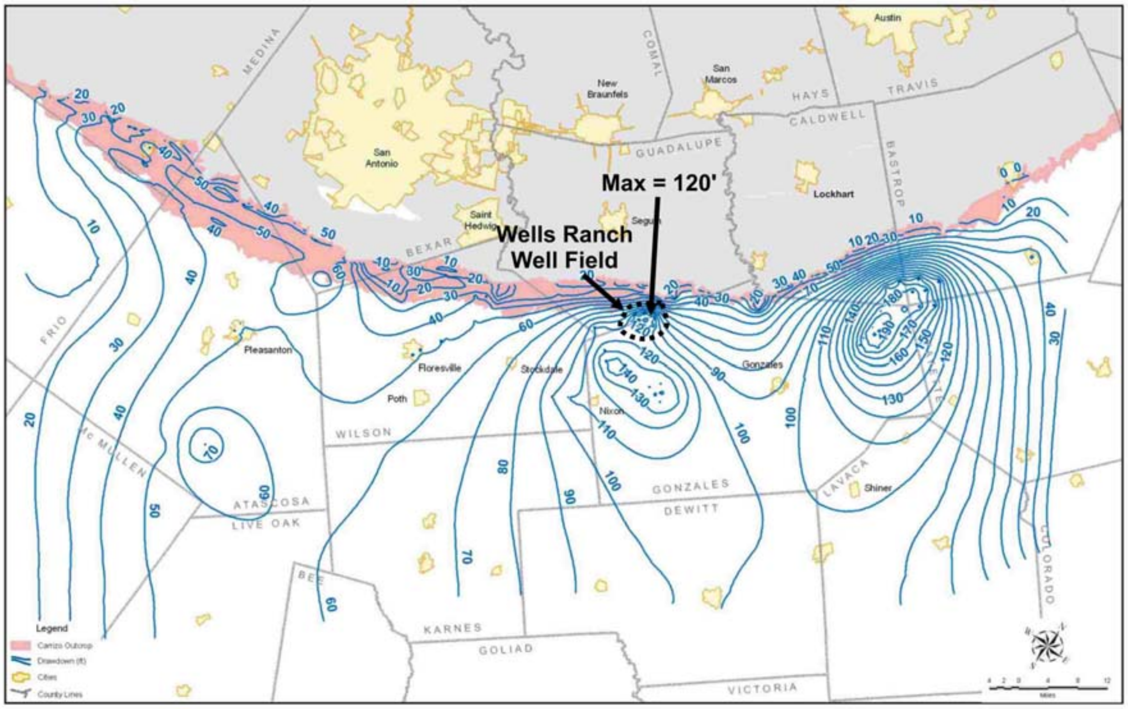


Figure 4C.24-4. SCCS 2002 to 2060 Drawdown: All Projects (with Hays/Caldwell Carrizo Project)

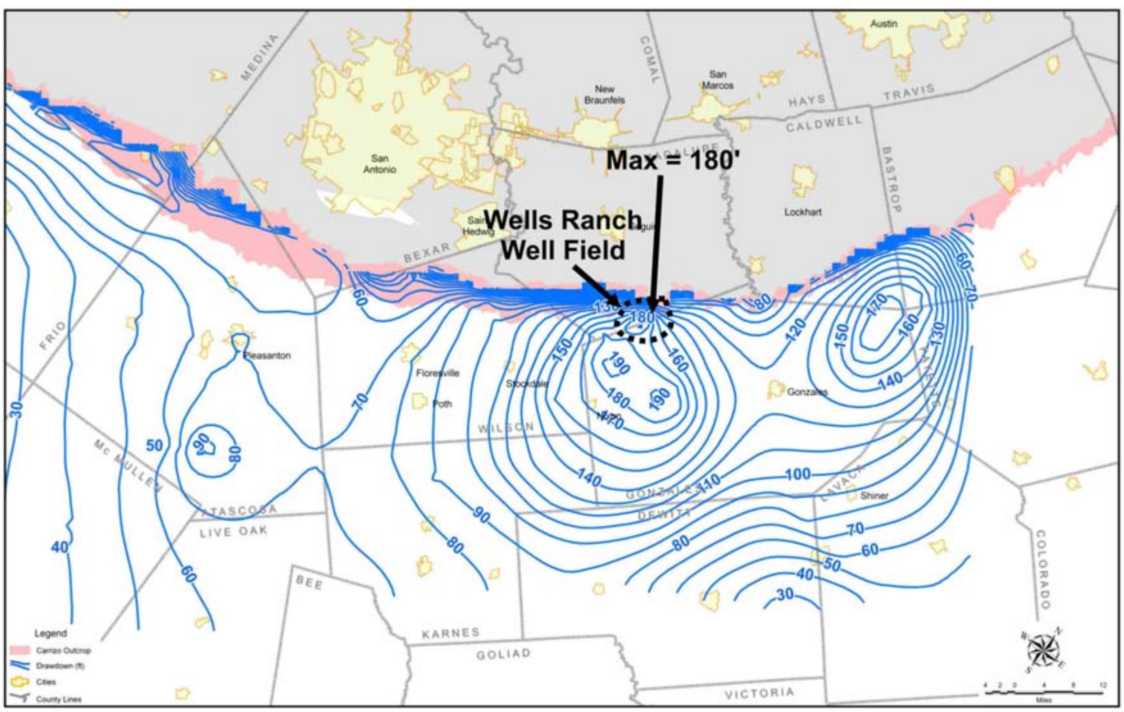


Figure 4C.24-5. SCWQSGAM 2002 to 2060 Drawdown: All Projects (with Hays/Caldwell Carrizo Project)

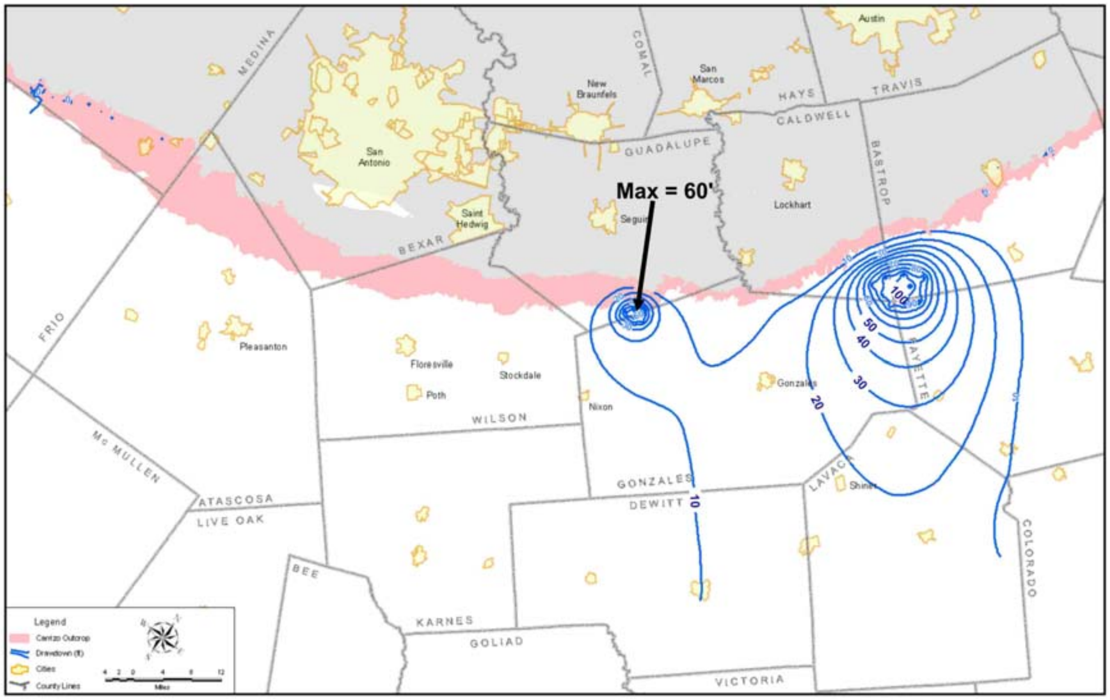


Figure 4C.24-6. SCCS 2002 to 2060 Drawdown Attributable to Wells Ranch and CRWA Dunlap Projects (and Hays/Caldwell Carrizo Project)

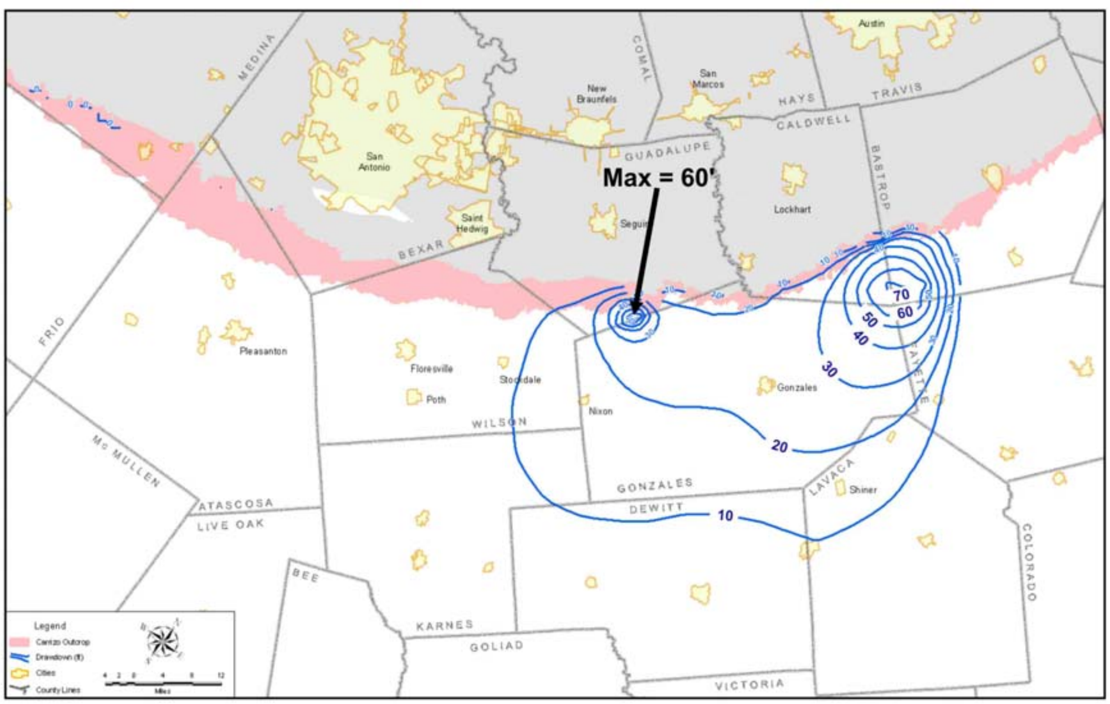


Figure 4C.24-7. SCWQSGAM 2002 to 2060 Drawdown Attributable to Wells Ranch and CRWA Dunlap Projects (and Hays/Caldwell Carrizo Project)

4C.24.3 Environmental Issues

The proposed Wells Ranch Project facilities include 62 percent of 18 wells in Gonzales and Guadalupe Counties, a collection system, water treatment plant, transmission pump station, and a 30-mile transmission pipeline. In addition to these groundwater facilities, a surface water treatment plant and pump station expansion at Lake Dunlap would be included. The proposed pipeline route for the groundwater portion of the CRWA Dunlap Project would originate at the Wells Ranch well field in eastern Guadalupe County, and travel in a northwest direction until it intersects with IH-10, then west along IH-10 and finally north, terminating at the Wagner Booster Station on FM 78.

The proposed pipeline route would traverse two of Omernik's[4] ecoregions: the East Central Texas Plains, and the westernmost reaches of the Texas Blackland Prairie. The project area would lie in the Texas Blackland Prairies and East Central Texas ecoregions.[5] The dominant vegetation of the Texas Blackland Prairies is mesquite, post oak, bluestems, switchgrass and blackjack oak supported by clay soils mixed with sandy loams. The Post Oak Savannah vegetational area is characterized by gently rolling to hilly terrain with an understory that is typically tall grass and an overstory that is primarily post oak *(Quercus stellata)* and blackjack oak *(Q. marilandica)*. The proposed pipeline corridor is a mosaic of the Post Oak Savannah and the Blackland Prairie ecoregions and could potentially include a wide variety of species. The land use for the area included in the pipeline route is composed of three major vegetation types. The northern section of the route above IH-10 is located in an area usually utilized for crop production. The center portion of the route is situated in a post oak wood and grassland mosaic, and the lower one third of the route traverses a post oak wood or forest.

Although the pipeline route parallels the Guadalupe River along a portion of its course, it does not cross any water sources listed by Texas Parks and Wildlife as Ecologically Significant River and Stream Segments.

Table 4C.24-3 lists rare and protected species that may have habitat in the project area. The Texas Biological and Conservation Data System maintained by TPWD Wildlife Diversity Branch maps several species and essential habitat in the vicinity of the pipeline route. Protected species appear to be primarily those dependent on shrubland or riparian habitat.

---

[4] Omernik, J. M, "Ecoregions of the conterminous United States," Annals of the Association of American Geographers, 77: 118-125, 1987.
[5] Gould, F.W., "The Grasses of Texas," Texas A&M University Press, College Station, Texas, 1975.

Table 4C.24-2
Important Species Having Habitat or Known to Occur In Guadalupe County*

Common Name	Scientific Name	Impact Value	Multiplier Based on Status	Adjusted Impact	Summary of Habitat Preference	Listing Entity		Potential Occurrence in County
						USFWS[1]	TPWD[1]	
American Peregrine Falcon	*Falco peregrinus anatum*	0	3	0	Open country; cliffs	DL	E	Nesting/Migrant
Arctic Peregrine Falcon	*Falco peregrinus tundrius*	0	2	0	Open country; cliffs	DL	T	Nesting/Migrant
Big Red Sage	*Salvia penstemonoides*	1	1	1	Endemic; Creekbeds and seepage slopes of limestone canyons			Resident
Cagle's Map Turtle	*Graptemys caglei*	1	2	2	Waters of the Guadalupe River Basin	C1	T	Resident
Cave Myotis Bat	*Myotis velifer*	0	1	0	Colonial & cave dwelling; hibernates in limestone caves of Edwards Plateau			Resident
Elmendorf's Onion	*Allium elmendorfii*	1	1	1	Endemic; deep sands derived from Queen City and similar Eocene formations			Resident
Guadalupe Bass	*Micropterus treculi*	1	1	1	Streams of eastern Edwards Plateau			Resident
Guadalupe Darter	*Percina sciera apristis*	1	1	1	Raceways of medium streams and rivers.			
Henslow's Sparrow	*Ammodramus henslowii*	1	1	1	Weedy fields or cut over areas; bare ground for running and walking			Nesting/Migrant
Interior Least Tern	*Sterna antillarum athalassos*	0	3	0	Inland river sandbars for nesting and shallow water for foraging	LE	E	Nesting/Migrant
Keeled Earless Lizard	*Holbrookia propinqua*	0	1	0	Coastal dunes, Barrier islands and sandy areas			Resident
Mountain Plover	*Charadrius montanus*	1	1	1	Shortgrass plains and fields, sandy deserts, plowed fields			Nesting/Migrant
Parks' Jointweed	*Polygonella parksii*	2	1	2	South Texas Plains; subherbaceous annual in deep loose sands, spring-summer			Resident
Plains Spotted Skunk	*Spilogale putorius interrupta*	0	1	0	Catholic; Wooded, brushy areas and tallgrass prairies			Resident

Table 4C.24-2 (continued)

Sandhill Woolywhite	*Hymenopappus carrizoanus*	2	1	2	Endemic; Open areas in deep sands derived from Carrizo and similar Eocene formations			Resident
Texas Garter Snake	*Thamnophis sirtalis annectens*	1	1	1	Varied, especially wet areas; bottomlands and pastures			Resident
Texas Horned Lizard	*Phrynosoma cornutum*	2	2	4	Varied, sparsely vegetated uplands		T	Resident
Texas Tortoise	*Gopherus berlandieri*	2	2	4	Open brush with grass understory; open grass and bare ground avoided; occupies shallow depressions at base of bush or cactus, underground burrows, under objects; active March-Nov		T	Resident
Timber/Canebrake Rattlesnake	*Crotalus horridus*	1	2	2	Bottomland hardwoods		T	Resident
Whooping Crane	*Grus americana*	0	3	0	Potential migrant	LE	E	Migrant
Wood Stork	*Buteo americana*	0	2	0	Prairie ponds, flooded pastures or fields; shallow standing water		T	Nesting/Migrant

[1] Texas Parks and Wildlife Department (TPWD), Unpublished 2005, March 2005, Data and Map Files of the Wildlife Science Research and Diversity Division maintained by TPWD, Austin, Texas.

* LE/LT=Federally Listed Endangered/Threatened E/SA, T/SA=Federally Listed Endangered/Threatened by Similarity of Appearance
C1=Federal Candidate for Listing DL, PDL=Federally Delisted/Proposed for Delisting NL=not Federally Listed E, T=State Listed Endangered/Threatened
PE, PT=Federally Proposed Endangered/ Threatened Blank = Rare, but no regulatory listing status

Threatened species possibly found within the project area include Cagle's Map Turtle (Graptemys caglei), Texas horned lizard (*Phrynosoma cornutum), Texas* tortoise (*Gopherus berlandieri),* and the timber/canebrake rattlesnake (*Crotalus horridus)*. The Cagle's map turtle is found only in the waters of the Guadalupe River Basin, the timber/canebrake rattlesnake can be found in woodlands consisting of oak and other hardwoods. The Texas tortoise prefers open brush with grass understory and usually occupies shallow depressions at the base of a bush or cactus, a similar habitat to the Texas horned lizard which occupies sparsely vegetated uplands.

In addition to these species, the proposed pipeline passes in the vicinity of several mapped species of concern: Mountain Plover *(Charadrius montanus),* Parks jointweed (*Polygonella parksii*), and Sandhill woollywhite (*Hymenopappus carrizoanus*). Additional species of concern which may be affected by the pipeline include the Guadalupe Bass *(Micropterus treculi),* Elmendorf's Onion (*Allium elmendorfii*), Texas Garter Snake (*Thamnophis sirtalis annectens)* and big red sage *(Salvia penstemonoides).*

Field surveys conducted at the appropriate phase of development should be employed to minimize the impacts of construction and operation on sensitive resources. Specific project features, such as well field, pipelines, and off-channel reservoirs generally have sufficient design flexibility to avoid most impacts or significantly mitigate potential impacts to geographically limited environmental and cultural resource sites.

Cultural resources protection on public lands in Texas is afforded by the Antiquities Code of Texas (Title 9, Chapter 191, Texas Natural Resource Code of 1977), the National Historic Preservation Act (P196-515), and the Archeological and Historic Preservation Act (PL93-291). Based on the review of available records housed at the Texas Archeological Research Laboratory in Austin, six cultural resource sites occur within a 1-mile corridor of the proposed project area (Table 4C.24-4). Considering that the owner or controller of the project will likely be a political subdivision of the State of Texas (i.e., river authority, municipality, county, etc.), they will be required to coordinate with the Texas Historical Commission prior to project construction. If the project will affect waters of the United States or wetlands, the project sponsor will also be required to coordinate with the U.S. Army Corps of Engineers regarding impacts to cultural resources.

Table 4C.24-4.
Previously Recorded Cultural Resource Sites within the Proposed Project Area

41GU3	41GU28	41GU35
41GU19	41GU29	41GU36

4C.24.4 Engineering and Costing

Groundwater for the Wells Ranch and CRWA Dunlap Projects will be developed by constructing 18 new wells, treatment facilities for chlorine disinfection and iron/manganese removal, and a new treated water conveyance pipeline to the CRWA Wagner Station. BMWD and CRWA will use a common well field, collection system, water treatment facilities, and transmission pipeline. Shared costs will be split according to the respective yield to each project with about 38 percent (3,400/9,000) assigned to the Wells Ranch Project and about 62 percent (5,600/9,000) assigned to the CRWA Dunlap Project. Surface water for the CRWA Dunlap project will be developed by expanding the capacities of the existing raw water pump station and water treatment plant at Lake Dunlap. CRWA indicates that the existing intake structure at Lake Dunlap is sized to be able to divert the entire 5,600 acft/yr; however, some improvements will be necessary to facilitate diversions at the assumed maximum rate of 11.4 cfs.

The CRWA Dunlap Project is planned to provide an additional 5,600 acft/yr to CRWA by 2010. The major facilities required for this water management strategy that are shared with the Wells Ranch Project include:

- 18 Carrizo Aquifer wells (500 gpm/well),
- Well field collection pipelines,
- 30-inch conveyance pipeline, and
- Groundwater treatment plant.

Additional major facilities required for this water management strategy are:

- Upgrade of Lake Dunlap surface water pump station, and
- Upgrade of surface water treatment plant.

The approximate locations of these facilities are displayed in Figure 4C.24-1.

Cost estimates are developed in accordance with the methodology for regional planning studies (Appendix A). Wells located in the Wells Ranch well field are assumed to be 800 feet deep, similar to nearby existing wells. A conceptual pipeline layout alignment has been identified, and a transmission pipeline diameter of 30 inches is estimated to be appropriate.

Costs for acquiring groundwater leases, annual lease payments, and anticipated third-party mitigation activities to compensate for lowered water levels in existing wells are included to be consistent with other water management strategies. Based on these assumptions, and on an assumed yield of 5,600 acft/yr, it is estimated that the water obtained through the CRWA Dunlap Project will have a unit cost of $956/acft, or $2.93/1,000 gallons (Table 4C.24-5).

Table 4C.24-5.
Cost Estimate Summary
CRWA Dunlap Project
Second Quarter 2002 Prices

Item	*Estimated Costs for Facilities*
Capital Costs	
Pump Station Expansion at Lake Dunlap (7.4 MGD)	$236,000
Shared Pump Station at Well Field (62% of 12.4 MGD) [1]	$1,670,000
Shared Transmission Pipeline (62% of 30 in dia., 30 miles) [1]	$9,771,000
Shared Well Field (62% of 18-500 GPM Wells) [1]	$6,012,000
Water Treatment Plant Expansion at Lake Dunlap (7.4 MGD)	$6,165,000
Shared Treatment Plant at Well Field (62% of 12.4 MGD) [1]	$5,577,000
Total Capital Cost	**$29,431,000**
Engineering, Legal Costs and Contingencies	$9,813,000
Environmental & Archaeology Studies and Mitigation	$617,000
Groundwater Lease Acquisition	$907,000
Mitigation Reserve for Impacts to Local Wells	$1,764,000
Land Acquisition and Surveying (131 acres)	$683,000
Interest During Construction (1 years)	$1,622,000
Total Project Cost	**$44,837,000**
Annual Costs	
Debt Service (6 percent, 30 years)	$3,063,000
Operation and Maintenance	
Wells, Pipeline, Pumps	$205,000
Water Treatment Plant	$1,489,000
Pumping Energy Costs (4,049,769 kW-hr @ 0.06 $/kW-hr)	$243,000
Purchase of Water (5,600 acft/yr @ 62.85 $/acft)	$352,000
Total Annual Cost	**$5,352,000**
Available Project Yield (acft/yr)	5,600
Annual Cost of Water ($ per acft)	$956
Annual Cost of Water ($ per 1,000 gallons)	$2.93

[1] Costs shown for shared facilities are about 62 percent (5,600 / 9,000) of the overall costs for facilities shared by the Wells Ranch and CRWA Dunlap Projects.

4C.24.5 Implementation Issues

Implementation of the CRWA Dunlap Project groundwater component could involve limited conflicts with other Carrizo groundwater management strategies under consideration, including Regional Carrizo for Bexar County, Hays/Caldwell Carrizo Project, and/or SSLGC Project Expansion, since each of these will be operating within common groundwater conservation districts.

This project was evaluated in conformance with the existing rules of the GCUWCD. Part of the supply developed by this project exceeds the amount of available water identified in the current GCUWCD management plan. The amount of water needed by the project that exceeds the available water in the management plan cannot be implemented unless and until permits are received from the GCUWCD. This project does not cause the GCUWCD management plan to be in conflict with the South Central Texas Regional Water Plan. See Public Comments and SCTRWPG Response Developed through Facilitation for Issue Number 6 in Section 10.2.2.3. Also, as stated previously, production from the Wells Ranch property in Guadalupe County is limited to 1,400 ac-ft/year in accordance with a settlement reached between BMWD and the Guadalupe County GCD.

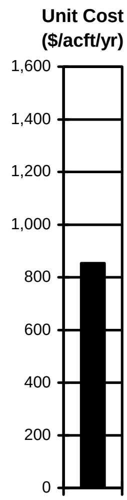
Any project involving production of groundwater from the Carrizo-Wilcox Aquifer in the South Central Texas Water Planning Region must address issues, including the following:

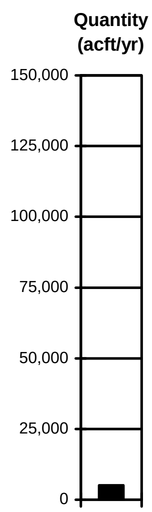
- Detailed feasibility evaluation including test drilling and aquifer and water quality testing, followed with more detailed groundwater modeling to confirm results of this preliminary evaluation.
- Impacts on:
  - Endangered and threatened species,
  - Water levels in the aquifer,
  - Baseflow in streams, and
  - Wetlands.
- Competition with others in the area for groundwater.
- Regulations by the Guadalupe County UWCD and GCUWCD, including the renewal of pumping permits at 5-year intervals.
- Water levels did not completely stabilize during the 59-year simulation. If all proposed pumpage continues at 100 percent of planned amounts, water levels could continue to decrease.

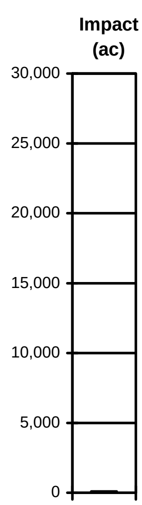
The proposed increase in the authorized diversion amount of CRWA's water right requires authorization from the TCEQ and environmental or other studies. As surface water from this project is to be used in Bexar County and other locations outside the Guadalupe River Basin, an interbasin transfer authorization must be obtained form TCEQ.

(This page intentionally left blank.)

2006 South Central Texas Regional Water Plan
Water Management Strategy Summary Sheet







Name: CRWA Siesta Project

Description: Water management strategy includes an amendment to CRWA's existing Siesta water right on Cibolo Creek (changing the authorized diversions from 42 acft/yr to 5,042 acft/yr), acquisition and consolidation of other existing water rights on Cibolo Creek, and purchase of reuse make-up water from SARA's Martinez Creek WWTPs. Facilities include an intake & pump station at the Siesta Cattle Company site, water treatment plant, and a 23-mile 20-inch pipeline to the existing FM 1518 elevated tank. Strategy has been sized for delivery on a peak month basis for municipal supply.

***Decade Needed*:** 2000 – 2010

Cost, Quantity of Water, and Land Impacted

Unit Cost of Water:	**$853**	**$/acft/yr**	**Treated Water Delivered**
Quantity of Water:	**5,042**	**acft/yr**	**Reliability = Firm**
Land Impacted:	**92**	**acres**	

Additional Considerations per Regional Water Planning Guidelines

Environmental Factors:

Threatened species include the Texas Horned Lizard and the Texas Tortoise.

Impacts on Water Resources:

Some reductions in streamflows in Cibolo Creek associated with greater utilization of existing water rights and the CRWA Amendment.

Impacts on Agricultural & Natural Resources:

Minimal, if any.

Other Relevant Factors per SCTRWPG:

Encourages beneficial use of available rights. The use of effluent from SARA's Martinez Creek WWTPs, as make-up water, is subject to necessary permitting and contractual agreements.

Comparison of Strategies to Meet Needs:

Limited conflicts with other recommended water management strategies including the Lower Guadalupe Water Supply Project.

Interbasin Transfer Issues:

None anticipated.

Third-Party Impacts of Voluntary Transfers:

None anticipated.

Regional Efficiency:

Utilizes reuse water as a make-up source, in lieu of storage or groundwater.

Water Quality Considerations:

Use of treated effluent as a make-up supply source may require added treatment.

(This page intentionally left blank.)

4C.25 CRWA Siesta Project

4C.25.1 Description of Water Management Strategy

The CRWA Siesta Project is based on diversions from Cibolo Creek in Wilson County under existing and amended water rights along with treated effluent from wastewater treatment facilities operated by San Antonio River Authority (SARA) as raw water sources for treatment and distribution as a new municipal water supply for CRWA members. The CRWA Siesta Project involves the acquisition/lease of additional water rights and the amendment of a surface water right presently held by CRWA in order to increase authorized diversions from Cibolo Creek by CRWA from 42 acft/yr to 5,042 acft/yr. The firm yield of the CRWA Siesta Project at the Siesta Cattle Company site is to be available to the CRWA members of LaVernia, SS Water Supply Corporation, East Central Water Supply Corporation, Bexar Metropolitan Water District, and to others via the existing CRWA Mid-Cities Pipeline (Figure 4C.25-1).

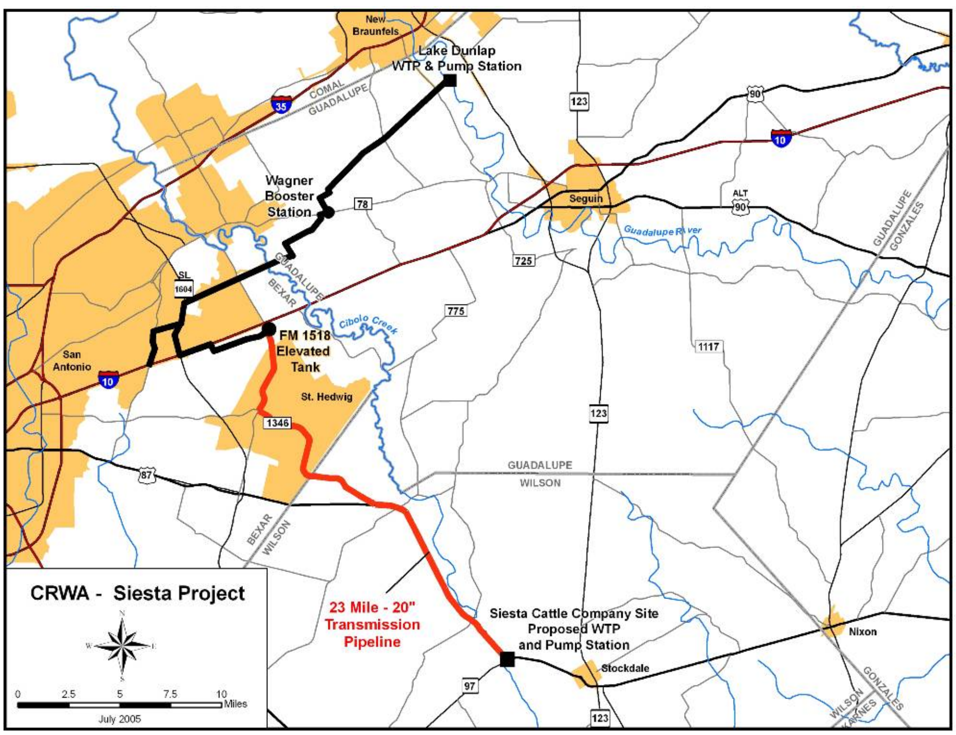


Figure 4C.25-1. CRWA Siesta Project

4C.25.2 Water Availability

As of July 2005, CRWA has acquired two water rights on Cibolo Creek – Certificate of Adjudication (CA) #19-1155 for 42 acft/yr (formerly held by the Siesta Cattle Company) and CA #19-1151 for 86 acft/yr (formerly held by Raymond D Hegwer et ux). CRWA has entered into agreements to lease water from two water rights holders on Cibolo Creek – CA #19-1152 for 35 acft/yr and CA #19-1157 for 117 acft/yr. In addition, CRWA is in negotiations to acquire/lease up to 455 acft/yr of additional water rights to be included in the CRWA Siesta Project. CRWA will be seeking to amend these water rights so that a common diversion point can be utilized at the Siesta Cattle Company site and to increase total authorized diversions at that point to 5,042 acft/yr.

The Guadalupe-San Antonio River Basin Water Availability Model (GSAWAM, as modified for regional water planning purposes) was used to quantify water available for diversion under the existing water rights CRWA has either already acquired/leased or is seeking to acquire/lease. Hydrologic simulations and calculations were performed subject to the General Assumptions for Applications of Hydrologic Models adopted by the South Central Texas Regional Water Planning Group and listed in Appendix B of Volume II.

The GSAWAM was also used to quantify the water available under a proposed amendment to the Siesta water right (CA #19-1155) thereby increasing authorized diversion by 4,307 acft/yr. The proposed amendment to CA #19-1155 was modeled as a new appropriation subject to environmental flow restrictions consistent with Consensus Criteria for Environmental Flow Needs (CCEFN). Table 4C.25-1 includes the streamflow statistics used in the application of CCEFN.

Water diverted for the CRWA Siesta Project under the various water rights acquisitions, leases, and amendments is shown in Figure 4C.25-2. In addition, Figure 4C.25-2 shows the make-up water necessary from SARA wastewater treatment plants on Martinez Creek to obtain a firm yield of 5,042 acft/yr. The long-term average (1934-1989) diversion from Cibolo Creek under the various water rights is 2,706 acft/yr, while the drought average (1947-1956) diversion is 1,493 acft/yr. The corresponding long-term and drought average make-up water requirements are 2,336 acft/yr and 3,549 acft/yr, respectively.

Table 4C.25-1.
Daily Naturalized Streamflow Statistics for Cibolo Creek at Falls City

Month	Median Flows - Zone 1 Pass-Through Requirement (cfs)	25th Percentile Flows - Zone 2 Pass-Through Requirement (cfs)
January	26.9	19.2
February	27.1	19.4
March	26.9	19.1
April	26.0	17.0
May	30.0	15.9
June	29.2	13.4
July	20.0	11.0*
August	16.0	11.0*
September	19.0	11.0*
October	22.1	13.0
November	26.0	15.2
December	26.2	16.7
Zone 3 Pass-Through Requirement (cfs)		11.0
* Zone 3 Pass-Through Requirement exceeds 25th Percentile Flow.		

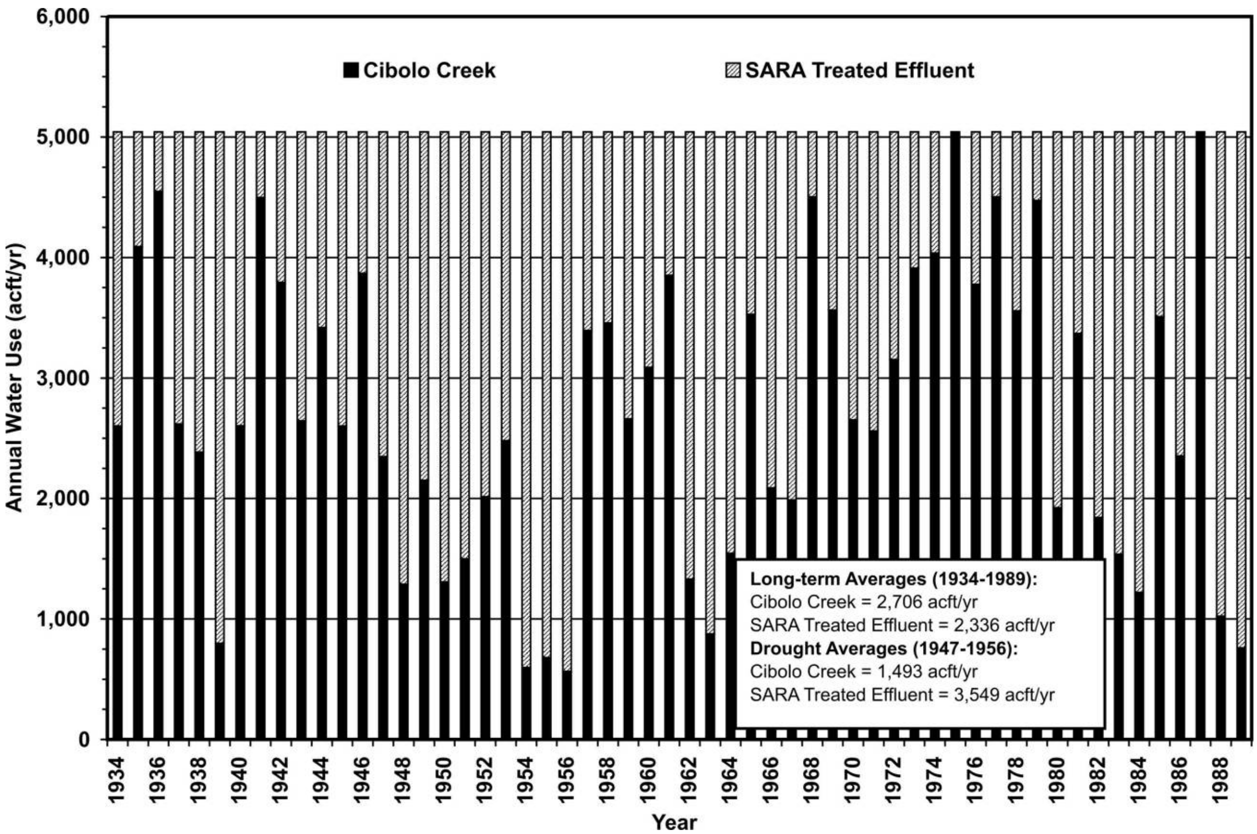


Figure 4C.25-2. CRWA Siesta Project – Water Supply Sources

Figure 4C.25-3 shows the monthly median streamflows and overall streamflow frequency for Cibolo Creek at Falls City with and without the CRWA Siesta Project. Percent changes in monthly median streamflow range from a high of an 11% decrease in October to essentially no change in the months of July and August. Streamflow statistics and surface water diversion presented herein are based on current levels of treated effluent.

4C.25.3 Environmental Issues

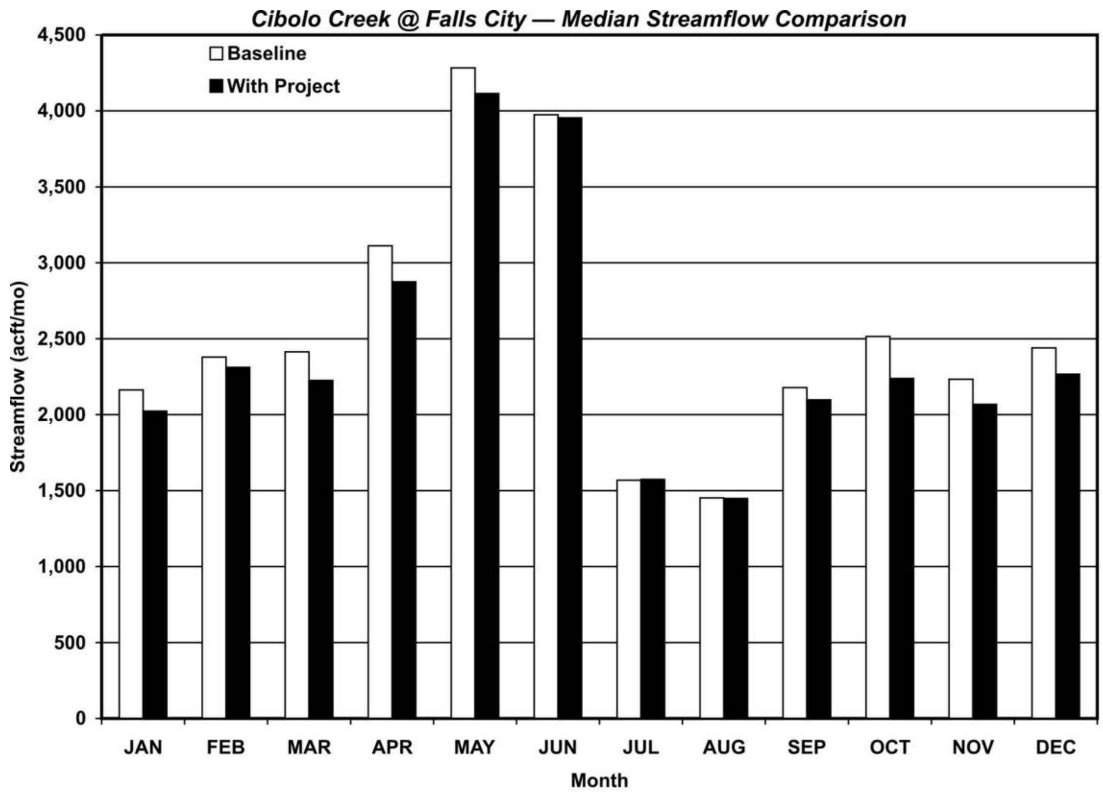
The CRWA Siesta Project facilities include an intake and pump station, water treatment plant, and a 23-mile pipeline to the existing FM 1518 elevated tank. The project area includes land primarily in the South Texas Plains vegetational area, with the northwestern end of the proposed pipeline entering into the edges of the Blackland Prairies vegetational area.[1] The vegetation of these areas of Bexar and Wilson County is now primarily composed of rangeland, crops and post-oak woodlands. Landforms of the project area are typically nearly level to gently rolling and are slightly-to-moderately dissected by streams which are tributaries of the San Antonio and Guadalupe Rivers.

The original vegetation of the South Texas Plains was a brushy chaparral-grassland with dense thickets of oaks and mesquites on the ridges and oak, pecan, and ash common along streams. Continued grazing and cessation of fires altered the vegetation to such a degree that the region south of San Antonio is now commonly called the South Texas Brush Country.[2] Thorny brush is the predominant vegetation type in this region, including mesquite (*Prosopis pubescens*) acacia (*Acacia greggii*), prickly pear (*Opuntia spp.)* and mimosa, among others. Grasses characteristic of these sandy loam soils are seacoast bluestem (*Schizachyrium scoparium* var. *littoralis),* tanglehead (*Heteropogon contortus),* and species of bluestem (*Bothriochloa), Paspalum,* windmill grass (*Chloris)* and lovegrass (*Eragrostis).* Many of these vegetational elements of the South Texas Brush Country are seen in the southern half of the proposed pipeline route.

The northern portion of the proposed pipeline route passes through the Blackland Prairie vegetational area, which is characterized by prairie grass and forbs. Most of this area is now cultivated in crops, however there are still small pockets of meadowland present which is

---

[1] Gould, F.W., "The Grasses of Texas," Texas A&M University Press, College Station, Texas, 1975.
2 Inglis, J.M., "A History of Vegetation on the Rio Grande Plain," Project W-84-R-Texas, Bulletin No. 45, Texas Parks and Wildlife Department. Austin, Texas, 1964.



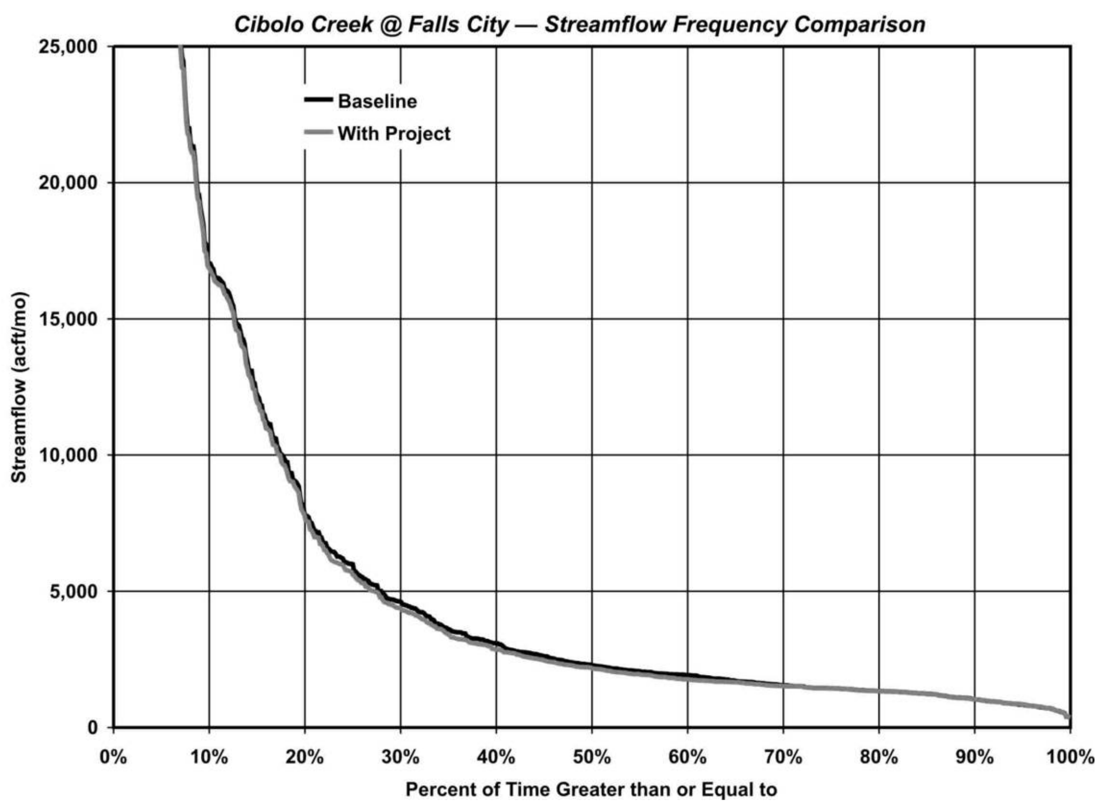


Figure 4C.25-3. CRWA Siesta Project — Streamflow Statistics

composed of climax tall grass vegetation. The dominant grass in this area is little bluestem, (*Schizachyrium scoparium* var. *frequens*), with other important grasses including big bluestem (*Andropogon gerardii)*, indiangrass (*Sorghastgrum nutans)*, switchgrass (*Panicum virgatum)*, and sideoats grama (*Bouteloua curtipendula)*. During the turn of the 20th century, about 98 percent of the Blackland Prairie was cultivated for crops. Livestock production has increased dramatically since that time, and now only about 50 percent of the area is used for cropland. Common woody plant species in this area include mesquite, huisache (*Acacia smallii*), oak (*Quercus sp.*) and elm (*Ulmus sp.*). Oak, elm, cottonwood (*Populus sp.*) and native pecan (*Carya*) are common along drainages.

Vertebrate fauna typifying these regions include the opossum, raccoon, weasel, skunk, white-tailed deer, and bobcat as well as a wide variety of amphibians, reptiles, and birds. The coyote and javelina are also common to the area, but are found mainly in brush/shrub areas while red and gray foxes are more common in woodlands.[3]

Plant and animal species listed by the USFWS and TPWD as endangered, threatened or rare in the project area are presented in Table 4C.25-2. The ranges of the endangered golden-cheeked warbler (*Dendroica chrysoparia*) and black-capped vireo (*Vireo atricapillus*) only extend into northern and western Bexar County and not Wilson County. Consequently, the presence of these species or their typical nesting habitat, in the vicinity of the proposed pipeline is unlikely.

Several species listed as threatened by the state may occur in the vicinity of the pipeline right of way. These include the Cagle's map turtle (*Graptemys caglei*), indigo snake (*Drymarchon corais erebennus)*, Texas horned lizard (*Phrynosoma cornutum*), Texas tortoise (*Gopherus berlandieri)* and black spotted newt (*Notophthalmus meridionalis*).

The only endangered, threatened species, or species of special concern identified as occurring on or in the vicinity of the proposed pipeline route by the Texas Biological and Conservation Data System (TXBCD) system files include Elmendorf's onion (*Allium elmendorfii*), big red sage (*Salvia penstemonoides)* and Parks jointweed (*Polygonella parksii)*. Both Elmendorf's onion and Parks' jointweed are found in deep sands. The big red sage usually grows along creek beds and seepage slopes of limestone canyons. These species of concern are considered to be rare, but are not protected by USFWS or TPWD.

[3] Jones, J.K. et al., "Annotated Checklist of Recent Land Mammals of Texas," Occasional Papers of the Museum OP-119, Texas Tech University, 1988.

Table 4C.25-2
Rare and Protected Species in the Project Area

Common Name	Scientific Name	Impact Value	Multiplier Based on Status	Adjusted Impact	Summary of Habitat Preference	Listing Entity		Potential Occurrence in County
						USFWS[1]	TPWD[1]	
American Peregrine Falcon	*Falco peregrinus anatum*	0	3	0	Open country; cliffs	DL	E	Nesting/Migrant
Arctic Peregrine Falcon	*Falco peregrinus tundrius*	0	2	0	Open country; cliffs	DL	T	Nesting/Migrant
Big Red Sage	*Salvia penstemonoides*	2	1	2	Endemic; Creekbeds and seepage slopes of limestone canyons			Resident
Black Bear	*Usus americanus*	0	2	0	Mountains, broken country, woods, brushlands, forests	T/SA; NL	T	Resident
Black-capped Vireo	*Vireo atricapillus*	2	3	6	Semi-open broad-leaved shrublands	LE	E	Nesting/Migrant
Black-spotted Newt	*Notophthalmus meridionalis*	1	2	2	Wet or temporally wet arroyos, canals, ditches, shallow depressions; aestivates underground during dry periods		T	Resident
Bracted Twistflower	*Streptanthus bracteatus*	1	1	1	Endemic; Shallow clay soils over limestone; rocky slopes			Resident
Braken Bat Cave Meshweaver	Cicurina venii	0	3	0	Small eyeless spider, in Karst features in western Bexar County.	LE		Resident
Cagle's Map Turtle	*Graptemys caglei*	1	2	2	Waters of the Guadalupe River Basin	C1	T	Resident
Cave Myotis Bat	*Myotis velifer*	0	1	0	Colonial & cave dwelling; hibernates in limestone caves of Edwards Plateau			Resident
Cokendolpher Cave Harvestman	*Texella cokendolpheri*	0	3	0	Small eyeless harvestman, karst features in north-central Bexar county.	LE		Resident
Comal Blind Salamander	*Eurycea tridentifera*	0	2	0	Endemic; Semi-troglobitic; Springs and waters of caves		T	Resident
Correll's False Dragon-Head	*Physostegia correllii*	1	1	1	Wet soils			Resident
Edwards Plateau Spring Salamander	*Eurycea sp. 7*	0	1	0	Troglobitic; Edwards Plateau			Resident
Elmendorf's Onion	*Allium elmendorfii*	2	1	2	Endemic; deep sands derived from Queen City and similar Eocene formations			Resident
Golden-Cheeked Warbler	Dendroica chrysoparia	1	3	3	Woodlands with oaks and old juniper	LE	E	Nesting/Migrant

Table 4C.25-2. Continued

Government Canyon Bat Cave Meshweaver	*Cicurina vespera*	0	3	0	Small, eyeless spider, karst features in northwestern Bexar County.	LE		Resident
Government Canyon Bat Cave Spider	*Neoleptoneta microps*	0	3	0	Small, eyeless or essentially eyeless spider; karst features in N and NW Bexar Co.	LE		Resident
Ground Beetle #1	*Rhadine exilis*	0	3	0	Eyeless beetle, karst features in northern Bexar County.	LE		Resident
Ground Beetle #2	Rhadine infernalis	0	3	0	Small eyeless ground beetle; karst features in northern and western Bexar County.	LE		Resident
Guadalupe Bass	*Micropterus treculi*	0	1	0	Streams of eastern Edwards Plateau			Resident
Helotes Mold Beetle	*Bastrisodes venyivi*	0	3	0	Small, essentially eyeless mold beetle; karst features in N and NW Bexar Co.	LE		Resident
Henslow's Sparrow	*Ammodramus henslowii*	1	1	1	Weedy fields or cut over areas; bare ground for running and walking			Nesting/Migrant
Indigo Snake	*Drymarchon corais erebennus*	1	2	2	Grass prairies and sand hills; usually thornbush woodland and mesquite savannah of coastal plain		T	Resident
Jaguarundi	*Felis yagouaroudi*	0	3	0	South Texas thick brushlands, favors areas near water	LE	E	Resident
Keeled Earless Lizard	*Holbrookia propinqua*	0	1	0	Coastal dunes, Barrier islands and sandy areas			Resident
Manfreda Giant-Skipper	*Stallingsia maculosus*	1	1	1	Larvae feed inside leaf shelter and pupae found in cocoon made of leaves fastened by silk			Resident
Madla's Cave Meshweaver	*Cicurina madla*	0	3	0	Small, eyeless or essentially eyeless spider; karst features in N and NW Bexar Co.	LE		Resident
Mimic Cavesnail	*Phreatodrobia imitata*	0	1	0	Subaquatic; wells in Edwards Aquifer			Resident
Mountain Plover	*Charadrius montanus*	0	1	0	Shortgrass plains and fields, sandy deserts, plowed fields			Nesting/Migrant
Ocelot	*Felis pardalis*	0	3	0	Dense chaparral thickets; mesquite-thorn scrub and live oak mottes; avoids open areas	LE	E	Resident
Parks' Jointweed	*Polygonella parksii*	2	1	2	South Texas Plains; subherbaceous annual in deep loose sands, spring-summer			Resident

Table 4C.25-2. Concluded

Plains Spotted Skunk	*Spilogale putorius interrupta*	0	1	0	Catholic; Wooded, brushy areas and tallgrass prairies			Resident
Robber Baron Cave Meshweaver	*Cicurina baronia*	0	3	0	Small, eyeless or essentially eyeless spider; karst features in N and NW Bexar Co.	LE		Resident
Sandhill Woolywhite	*Hymenopappus carrizoanus*	1	1	1	Endemic; Open areas in deep sands derived from Carrizo and similar Eocene formations			Resident
Spot-tailed Earless Lizard	*Holbrookia lacerata*	1	1	1	Oak-juniper woodlands and mesquite-prickly pear			Resident
Texas Garter Snake	*Thamnophis sirtalis annectens*	1	1	1	Varied, especially wet areas; bottomlands and pastures			Resident
Texas Horned Lizard	*Phrynosoma cornutum*	1	2	2	Varied, sparsely vegetated uplands		T	Resident
Texas Salamander	*Eurycea neotenes*	0	1	0	Endemic, from springs, seeps and caves.			Resident
Texas Tortoise	*Gopherus berlandieri*	2	2	4	Open brush with grass understory; open grass and bare ground avoided; occupies shallow depressions at base of bush or cactus, underground burrows, under objects; active March-Nov		T	Resident
Toothless Blindcat	*Trogloglanis pattersoni*	0	1	0	Fish.		T	Resident
Whooping Crane	*Grus americana*	0	3	0	Potential migrant	LE	E	Migrant
White-faced Ibis	*Plegadis chihi*	0	2	0	Prefers freshwater marshes.		T	
Widemouth Blindcat	*Satan eurystomus*	0	1	0	Fish		T	Resident
Wood Stork	*Buteo americana*	0	2	0	Prairie ponds, flooded pastures or fields; shallow standing water		T	Nesting/Migrant
Zone-tailed Hawk	*Buteo albonotatus*	0	2	0	Arid, open country including deciduous or pine-oak woodland; nests in various habitats and sites		T	Nesting/Migrant

[1]Texas Parks and Wildlife Department (TPWD), Unpublished 2005, March 2005, Data and Map Files of the Wildlife Science Research and Diversity Division maintained by TPWD, Austin, Texas.

* LE/LT=Federally Listed Endangered/Threatened E/SA, T/SA=Federally Listed Endangered/Threatened by Similarity of Appearance
C1=Federal Candidate for Listing DL, PDL=Federally Delisted/Proposed for Delisting NL=not Federally Listed E, T=State Listed Endangered/Threatened
PE, PT=Federally Proposed Endangered/ Threatened Blank = Rare, but no regulatory listing status

4C.25.3.1 Cultural Resources

Field surveys conducted at the appropriate phase of development should be employed to minimize the impacts of construction and operation on sensitive resources. Specific project features, such as well field, pipelines, and off-channel reservoirs generally have sufficient design flexibility to avoid most impacts or significantly mitigate potential impacts to geographically limited environmental and cultural resource sites.

Cultural resources protection on public lands in Texas is afforded by the Antiquities Code of Texas (Title 9, Chapter 191, Texas Natural Resource Code of 1977), the National Historic Preservation Act (P196-515), and the Archeological and Historic Preservation Act (PL93-291). Based on the review of available records housed at the Texas Archeological Research Laboratory in Austin, seventeen cultural resource sites occur within a 1-mile corridor of the proposed project area. Considering that the owner or controller of the project will likely be a political subdivision of the State of Texas (i.e., river authority, municipality, county, etc.), they will be required to coordinate with the Texas Historical Commission prior to project construction. If the project will affect waters of the United States or wetlands, the project sponsor will also be required to coordinate with the U.S. Army Corps of Engineers regarding impacts to cultural resources.

Table 4C.25-2.
Previously Recorded Cultural Resource Sites within the Proposed Project Area

41WN44	41WN53	41WN60	41WN107
41WN48	41WN54	41WN78	41WN108
41WN50	41WN55	41WN80	41WN109
41WN51	41WN58	41WN88	41WN110
41WN52			

4C.25.4 Engineering and Costing

Facilities for the CRWA Siesta Project include a raw water intake and pump station and a water treatment plant at the Siesta Cattle Company site as well as a 23-mile 20-inch treated water transmission pipeline to the existing FM 1518 elevated tank, part of the existing CRWA Mid-Cities Pipeline. Facilities have been sized to meet peak month demands. For costing purpose only, it is assumed that the entire 5,042 acft/yr would be delivered to the FM 1518 elevated tank.

Cost estimates were developed in accordance with the methodology for regional planning studies (Appendix A).

As suggested by CRWA, water rights acquisition costs are based on a one-time cost of $500/acft and lease costs are based on an annual cost of $50/acft/yr. Table 4C.25-3 contains the cost estimate for the CRWA Siesta Project. The capital cost for the facilities of the CRWA Siesta Project, including $292,000 for the acquisition of 583 acft/yr in water rights, is $23,940,000. With the inclusion of other project costs (contingencies, environmental, land acquisition, etc), the total project cost is $34,544,000. The annual cost for the CRWA Siesta Project, including amortization and O&M, is $4,297,000, yielding a unit cost of water of $853/acft/yr or $2.62/1,000-gallons.

4C.25.5 Implementation Issues

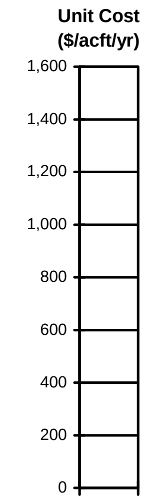
Potential issues or challenges associated with implementation of the CRWA Siesta Project could include:

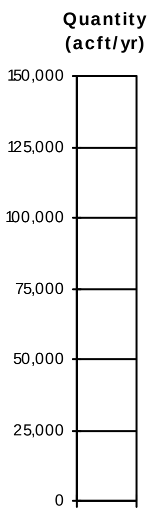
- Purchase or lease agreements with water rights holders on Cibolo Creek.
- Permit amendments for each of the water rights to be purchased or leased in order to allow diversion from a common point at the Siesta Cattle Company site.
- Permit amendment for the Siesta water right (CA #19-1155) to authorize increased diversions.
- Agreement between CRWA and SARA for the purchase and use of treated effluent from the SARA wastewater treatment plants on Martinez Creek.
- SARA to obtain an authorization for the bed and banks transfer of treated effluent from the discharge points along Martinez Creek to the Siesta Cattle Company site.

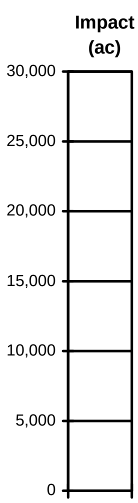
Table 4C.25-3.
Cost Estimate Summary
CRWA Siesta Project
Second Quarter 2002 Prices

Item	***Estimated Costs for Facilities (2nd Quarter 2002)***
Capital Costs	
Intake and Pump Station (7.0 MGD)	$3,036,000
Transmission Pipeline (20 in dia., 23 miles)	$8,425,000
Transmission Pump Station	$2,172,000
Water Treatment Plant (7.0 MGD)	$10,015,000
Acquisition of Water Rights (583 acft/yr)	$292,000
Total Capital Cost	**$23,940,000**
Engineering, Legal Costs and Contingencies	$7,856,000
Environmental & Archaeology Studies and Mitigation	$594,000
Land Acquisition and Surveying (92 acres)	$825,000
Interest During Construction (1 years)	$1,329,000
Total Project Cost	**$34,544,000**
Annual Costs	
Debt Service (6 percent, 30 years)	$2,510,000
Operation and Maintenance	
Intake, Pipeline, Pump Station	$211,000
Water Treatment Plant	$788,000
Pumping Energy Costs (5,945,192 kW-hr @ 0.06 $/kW-hr)	$357,000
Water Rights Leases (152 acft/yr)	$8,000
Purchase of Treated Effluent (5,644[1] acft/yr @ 75 $/acft)	$423,000
Total Annual Cost	**$4,297,000**
Available Project Yield (acft/yr)	5,042
Annual Cost of Water ($ per acft)	$853
Annual Cost of Water ($ per 1,000 gallons)	$2.62

2006 South Central Texas Regional Water Plan
Water Management Strategy Summary Sheet







Name: Local Storage

Description: The Local Storage water management strategy is included to explicitly recognize that storage is needed at several locations within the region in order to firm up supplies from run-of-river diversions and to ensure that supplies delivered through long distance conveyance facilities are available during drought and of sufficient quantity to meet daily and seasonal demands. The addition of Local Storage is consistent with the 2006 Regional Water Plan, if necessary authorizations are obtained pursuant to Texas Commission on Environmental Quality (TCEQ) rules and applicable law.

***Decade Needed*:** 2010 – 2060

Cost, Quantity of Water, and Land Impacted

Unit Cost of Water:	**Variable**	**$/acft/yr**	**Raw or Treated Water**
Quantity of Water:	**Variable**	**acft/yr**	**Reliability = Firm**
Land Impacted:	**Variable**	**acres**	

Additional Considerations per Regional Water Planning Guidelines

Environmental Factors:

Must consider effects associated with construction of new facilities, including aquatic and terrestrial habitats, threatened and endangered species, and cultural resources in accordance with applicable state & federal requirements.

Impacts on Water Resources:

Would be designed to take advantage of high flow conditions, and therefore would have minimal to no effects.

Impacts on Agricultural & Natural Resources:

Minimal, if any.

Other Relevant Factors per SCTRWPG:

Improves efficiencies and reliability of other water management strategies.

Comparison of Strategies to Meet Needs:

Unit cost highly variable depending on location relative to water sources, proximate construction materials, land use, and/or aquifer characteristics.

Interbasin Transfer Issues:

None anticipated.

Third-Party Impacts of Voluntary Transfers:

None anticipated.

Regional Efficiency:

Increases efficiency and reliability of other strategies.

Water Quality Considerations:

Depends upon source water, but likely not of significant concern.

(This page intentionally left blank.)

4C.26 Local Storage

4C.26.1 Description of Water Management Strategy

Water management strategies of the 2006 South Central Texas Regional Water Plan are sized and scheduled to meet seasonal and daily variations of demand, but, without storage, some current and proposed supplies may not be fully reliable during extended droughts. Several recommended strategies involve long distance pipelines of more than 125 miles in length that will be supplied from a combination of run-of-river diversions and groundwater. Thus, the need for surface reservoirs, large scale Aquifer Storage and Recovery (ASR) systems, or multipurpose reservoirs that are adequate in size to store surplus flows of surface water during periods of high streamflows, including flood flows, to be available during extended periods of drought. The Local Storage water management strategy involves implementing such ASR and/or surface storage facilities.

The San Antonio Water System (SAWS) has implemented a large scale ASR program, and is expanding its size for the purpose of storing and recovering surplus Edwards Aquifer water to meet seasonal peak demands, and the Cities of Victoria and San Marcos have indicated to the SCTRWPG a need for such storage as a part of their water plans to meet their respective water needs. SAWS may consider further expansions of its ASR program for multi-year storage to develop additional supply.

If the water management concern is a supply for emergencies or drought, water could be stored in the Carrizo or Gulf Coast Aquifers for several years before it is recovered. Water treatment capacity necessary to meet peak day demands may be available at non-peak times (fall, winter, and spring) to treat water for aquifer storage and subsequent recovery. Thus, a Local Storage component that is integrated into the water production and water treatment system has the potential to reduce costs and increase reliability and efficiency of the water management strategies necessary to meet projected need.

Cases for which local storage is needed include, off-channel storage for run-of-river diversions from the San Marcos River by San Marcos, gravel pit systems for Victoria to firm up run-of-river diversions from the Guadalupe River, and terminal or seasonal balancing storage for the Lower Guadalupe Water Supply Project (LGWSP) and the Lower Colorado River Authority/San Antonio Water System Project (LSWP). Terminal storage helps meet seasonal and daily peaks, allows for economical uniform long distance delivery, and provides short-term supply in the event of transmission system outages. The Surface Water Rights water management strategy (4C.11) has been included in the regional plan to explicitly recognize that use of water supplies made available under existing water rights by lease or purchase agreements between willing buyers and willing sellers is consistent with the 2006 South Central Texas Regional Water Plan. The addition of local storage is also consistent with the 2006 Regional Water Plan, if necessary authorizations are obtained pursuant to Texas Commission on Environmental Quality (TCEQ) rules and applicable law.

4C.26.2 Available Yield

Available yield associated with local storage is typically determined using the applicable surface water availability model (WAM) to simulate operations of the respective water management strategies. The Guadalupe – San Antonio River Basin WAM,1 the Nueces River Basin WAM,2 and the Edwards Aquifer Groundwater Availability Model (GAM) are the primary tools applicable for consideration of surface and groundwater flows in the South Central Texas Regional Water Planning Area (Region L).

4C.26.3 Environmental Issues

Potential environmental issues associated with implementation of the Local Storage water management strategy include consideration and mitigation of affected aquatic and terrestrial habitats, cultural resources, and threatened and endangered species, in accordance with applicable state and federal requirements.

4C.26.4 Engineering and Costing

Estimated costs for development of local storage are highly variable depending upon location relative to water source(s), proximate construction materials, present land use, and/or aquifer characteristics.

[1] HDR Engineering, Inc., “Water Availability in the Guadalupe – San Antonio River Basin,” Texas Natural Resource Conservation Commission, December 1999.
[2] HDR Engineering, Inc., “Water Availability in the Nueces River Basin,” Texas Natural Resource Conservation Commission, October 1999.

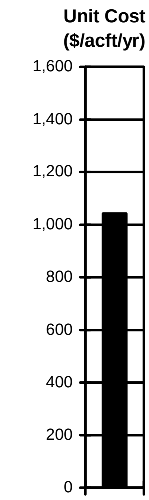
4C.26.5 Implementation Issues

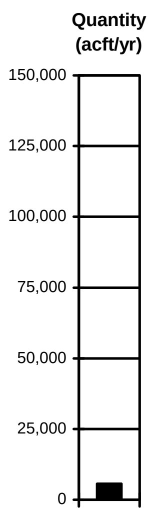
Potentially significant implementation issues associated with the Local Storage water management strategy include the following:

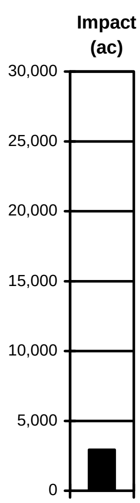
- Quantification and consideration of any potential effects on water rights, streamflows, and freshwater inflows to bays and estuaries to the extent required by TCEQ rules and applicable state and federal law.
- Run-of-river water rights often require surface storage and/or groundwater to firm up supply for municipal water use and a determination as to the most economically feasible of these is necessary.
- Acquisition of State, Federal, and Local permits.
- Environmental studies.
- Relocations of affected roads, railroads, utilities, and cultural resources.

(This page intentionally left blank.)

2006 South Central Texas Regional Water Plan
Water Management Strategy Summary Sheet







Name: **Lockhart Reservoir (G-21)**

Description: The Lockhart Reservoir site is located on Plum Creek, a tributary to the San Marcos River, north of Lockhart in Caldwell County. At elevation 482 ft-msl, the conservation pool capacity would be 50,000 acft. Facilities include a reservoir, intake, pump station, 16-inch 2-mile transmission pipeline, and water treatment plant near Lockhart. Strategy has capacity to meet projected needs of Lockhart and other water user groups in the area.

***Decade Needed*:** 2010+

Cost, Quantity of Water, and Land Impacted

Unit Cost of Water:	**$1,042**	**$/acft/yr**	**Treated Water Delivered**
Quantity of Water:	**5,627**	**acft/yr**	**Reliability = Firm**
Land Impacted:	**2,921**	**acres**	

Additional Considerations per Regional Water Planning Guidelines

Environmental Factors:
Reservoir would inundate approximately 2910 acres of land, including a 5-mile segment of Plum Creek. A potential stream & wetland mitigation area associated with TX130 has been identified immediately upstream of the dam site. There are no listed protected species in the project area.

Impacts on Water Resources:
Reduced streamflow immediately below dam. Consensus Criteria for Environmental Flow Needs was used in determining reservoir pass-through requirements based on reservoir content.

Impacts on Agricultural & Natural Resources:
Land inundated by the reservoir includes both crop and range land.

Other Relevant Factors per SCTRWPG:
Some questions regarding economic feasibility compared to alternative supply sources. Local government support expressed in preparation of 2001 Regional Water Plan. Currently, no new construction in the proposed reservoir pool, however, the alignment of TX130 passes immediately downstream of the dam site.

Comparison of Strategies to Meet Needs:
Moderate unit cost. No significant conflicts with other recommended water management strategies.

Interbasin Transfer Issues:
Not applicable.

Third-Party Impacts of Voluntary Transfers:
Not applicable.

Regional Efficiency:
The strategy is a new supply proximate to Lockhart and other WUGs in and around Caldwell County.

Water Quality Considerations:
None of significant concern.

(This page intentionally left blank.)

4C.27 Lockhart Reservoir

4C.27.1 Description of Water Management Strategy

The Lockhart dam and reservoir project is located at river mile 30.5 on Plum Creek (drainage area of 118 square miles), a tributary of the San Marcos River, just north of Lockhart in Caldwell County. Forrest and Cotton, Inc. first proposed the project in 1959 in their "Report on Supplement to the Initial Plan of Development of the Guadalupe-Blanco River Authority." The City of Lockhart's primary source of municipal water supply is groundwater, and the Lockhart project was proposed to provide additional municipal and industrial water to the local area. The location of the project is shown in Figure 4C.27-1.

Forest and Cotton developed a preliminary design for the Lockhart project based on a field inspection, as adequate topographic information was not available at the time. The dam embankment, as proposed, would be approximately 5,900 feet long with a top-of-dam crest elevation of 508 ft-msl (maximum dam height of 73 feet), to impound runoff from the 118 square mile watershed. The spillway system would consist of a 250-foot-long, broad-crested weir, with crest at elevation 482 ft-msl. The spillway design flood elevation would be 502.2 ft-msl, inundating approximately 5,430 acres. The reservoir would have a conservation pool capacity of 50,000 acft at elevation 482 ft-msl, permanently inundating 2,910 acres along a 5-mile segment of Plum Creek.

4C.27.2 Water Availability

The GSA Model[1] was used to estimate daily total streamflow and unappropriated streamflow available at the reservoir site. General assumptions for this application of the GSA Model are as adopted by the South Central Texas Regional Water Planning Group for use in preparation of the 2001 Regional Water Plan[2].

For modeling purposes, streamflows for Plum Creek near Luling (USGS# 08173000), adjusted for the difference in drainage area between the gage and the reservoir site, were assumed representative of inflows to the proposed reservoir. These flows are the naturalized flows at the reservoir site, adjusted to account for upstream water rights and return flows.

[1] HDR Engineering, Inc., "Guadalupe-San Antonio River Basin Recharge Enhancement Study," Edwards Underground Water District, September 1993.
[2] Updated hydrologic and firm yield analyses for Lockhart Reservoir were not included in the approved scope of work and budget for development of the 2006 South Central Texas Regional Water Plan.

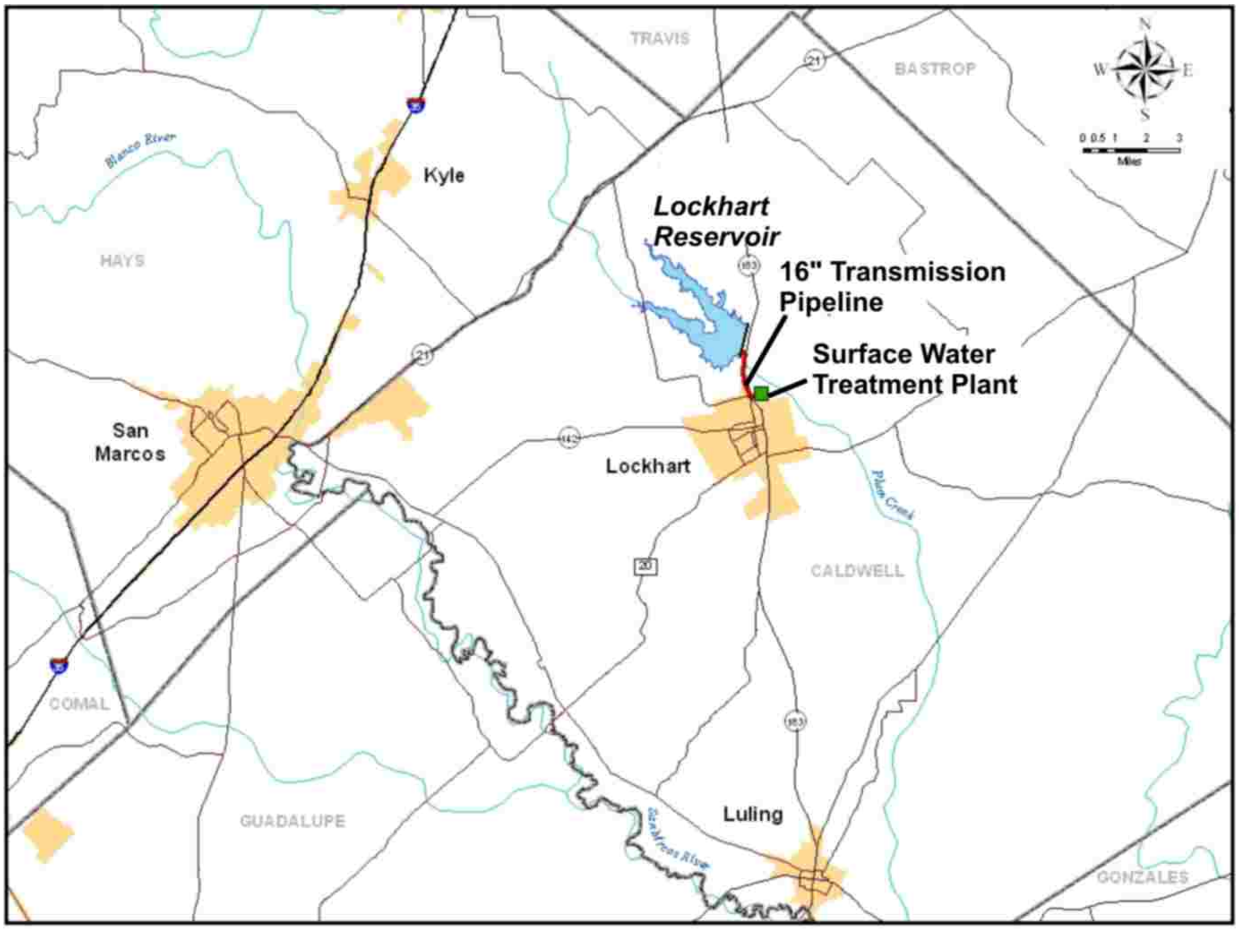


Figure 4C.27-1. Lockhart Reservoir Location Map

The GSA Model computes streamflow available for impoundment without causing increased shortages to downstream rights.

The firm yield of the Lockhart Reservoir was computed using the inflows and pass-through flows computed by the GSA Model and a modified version of the SIMDLY reservoir operation model (originally written by the TWDB). The streamflow statistics used to determine the pass-through requirements under Consensus Criteria for Environmental Flow Needs (CCEFN) are presented in Table 4C.27-1. Subject to a uniform seasonal demand pattern, the firm yield of the project is 5,627 acft/yr (which represents a reliable supply based on the 1934 to 1989 historical period of hydrologic record). In order to calculate an accurate firm yield estimate, the reservoir was assumed full at the start of the SYMDLY simulation, due to extremely low naturalized flows in 1934. Available flows for 1935 and 1936 are sufficient to fill the reservoir, accounting for evaporation and the estimated firm yield.

Table 4C.27-1
Daily Naturalized Streamflow Statistics for Lockhart Reservoir

Month	***Median Flows - Zone 1 Pass-Through Requirement (cfs)***	***25th Percentile Flows - Zone 2 Pass-Through Requirement (cfs)***
January	14.1	7.1
February	18.1	8.1
March	14.6	6.6
April	12.1	5.5
May	16.1	5.5
June	12.1	4.0
July	5.0	2.0*
August	2.0	2.0*
September	4.0	2.0*
October	5.5	2.0*
November	8.1	4.0
December	10.1	5.0
Zone 3 Pass-Through Requirement (cfs)		2.0
** Zone 3 Pass-Through Requirement exceeds 25th Percentile Flow.*		

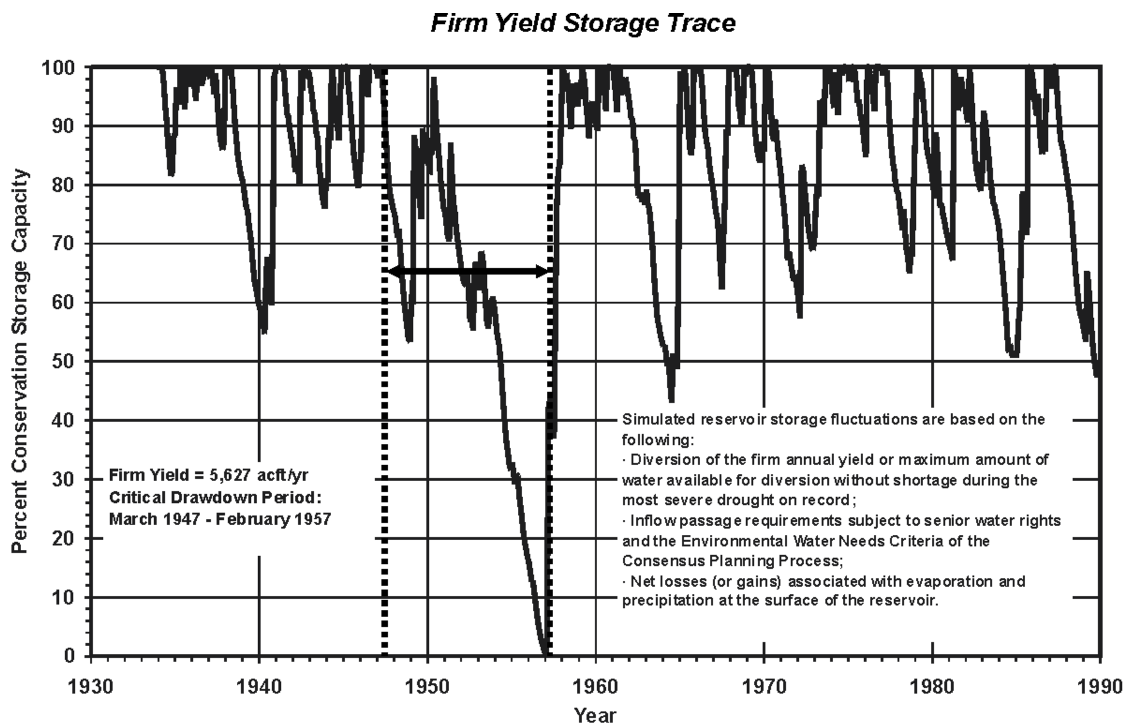
Figure 4C.27-2 illustrates the simulated Lockhart Reservoir storage fluctuations for the 1934 to 1989 historical period, subject to the firm yield of 5,627 acft/yr. Simulated reservoir storages remain above the Zone 2 trigger level (80 percent capacity) about 60 percent of the time and above the Zone 3 trigger level (50 percent capacity) about 92 percent of the time over the 1934 to 1989 historical period. Figure 4C.27-3 illustrates the changes in streamflow medians and frequencies caused by the reservoir at the project location and for the Guadalupe River at the Saltwater Barrier. Monthly median streamflows in Plum Creek would be reduced about 47 percent at the project site. Monthly median streamflows at the Saltwater Barrier would be reduced by about 1 percent.

4C.27.3 Environmental Issues

The Lockhart Reservoir project involves dam construction and inundation of approximately 2,910 acres along a 5-mile reach of Plum Creek, a tributary of the San Marcos River. The proposed reservoir site is located in north Caldwell County within the Texas Blackland Prairies ecoregion,3 in the Blackland Prairie vegetational area of Texas,4 and in the

---

[3] Omernik, James M., "Ecoregions of the Conterminous United States," Annals of the Association of American Geographers, 77(1), pp. 118-125, 1986.
[4] Gould, F.W., "The Grasses of Texas," Texas A&M University Press, Texas Agricultural Experiment Station, College Station, Texas, 1962.



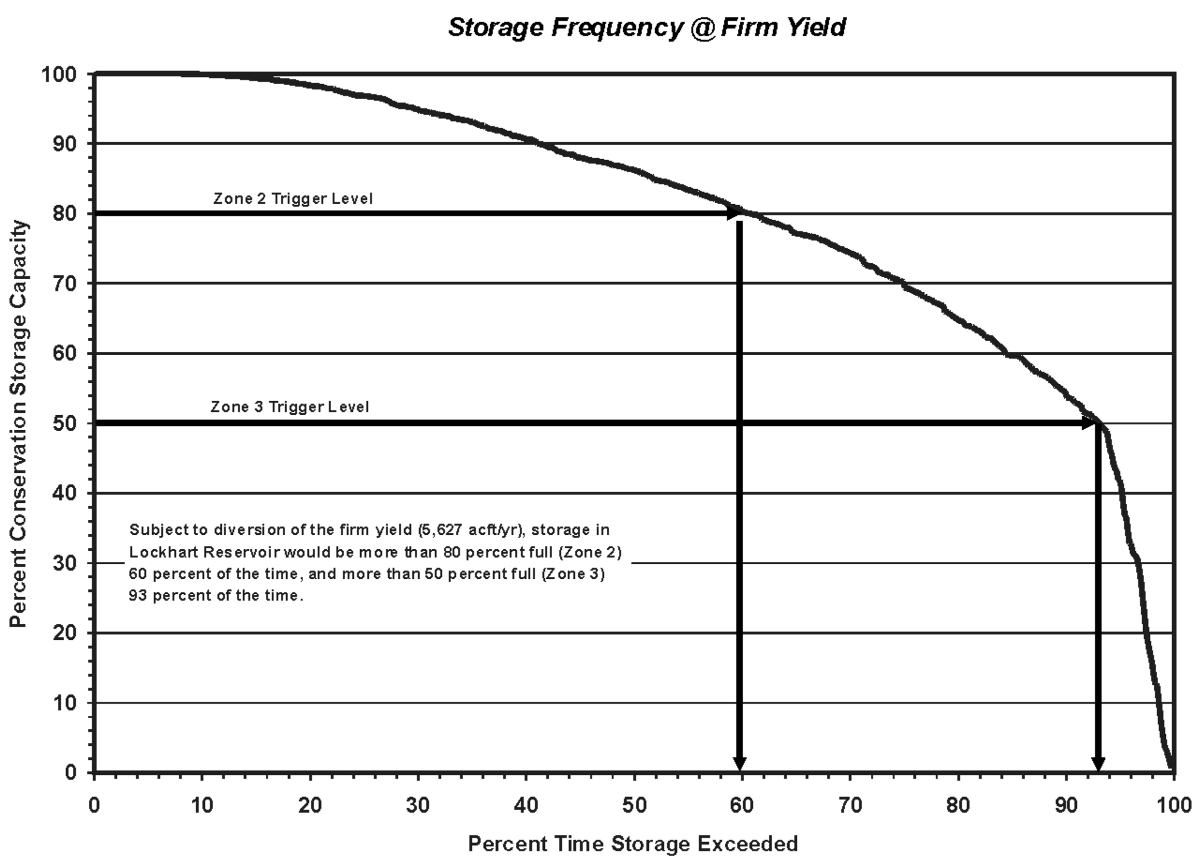


Figure 4C.27-2. Lockhart Reservoir Storage Considerations

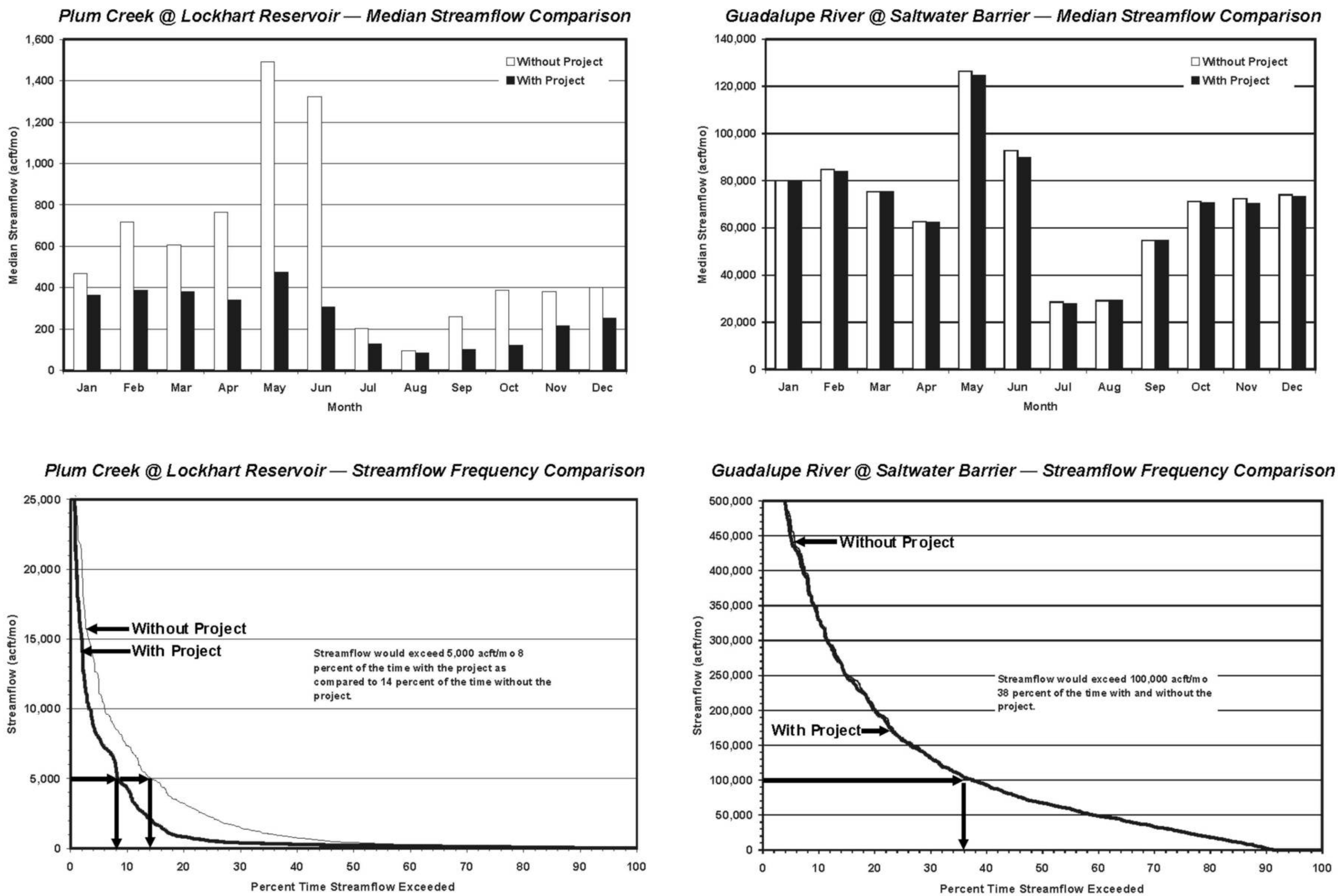


Figure 4C.27-3. Lockhart Reservoir Streamflow Comparisons

Texan biotic province.[5] Vegetation types within the Lockhart Reservoir project area include crops (30 percent), native and introduced grasses (25 percent), brushland and shrubland (38 percent), small quantities of woodlands (4 percent), and intermittent river and palustrine scrub/shrub and forested wetlands (3 percent).

Within the proposed Lockhart Reservoir site, Heiden clays, which are frequently eroded, are found on uplands with slopes ranging from 3 to 8 percent. They are well-drained and frequently used for crops or pasture. Houston black clays are found on smooth uplands. They are moderately well drained and are used for crops. Trinity clays have formed in calcareous, clayey, alluvial sediments on floodplains along streams where slopes are less than 1 percent. These areas are used predominantly for crops and improved pasture. Frequently flooded Trinity soils are on nearly level floodplains. These soils are flooded several times a year and are used mostly as pasture.

The primary impacts that would result from construction and operation of the Lockhart Reservoir include conversion of existing habitats and land uses within the conservation pool to open water, and potential downstream effects due to modification of the existing flow regime. The Lockhart Reservoir would permanently inundate 2,910 acres below 482 ft-msl. Approximately 1,600 acres of grassland and cropland, 1,106 acres of brushland and shrubland, 116 acres of woodland, 37 acres of riverine habitat, and 51 acres of wetlands would be converted to open water upon reservoir filling. Based on available information, no communities or other special resources are located within the reservoir area. Indirect effects of reservoir construction may include land use changes in the area surrounding the reservoir and in mitigation areas that may be converted to alternate uses to compensate for losses of terrestrial habitat.

Potential downstream impacts would include modification of the streamflow regime below the dam and a negligible reduction of freshwater inflows to the Guadalupe Estuary. At the project site, monthly median flows would be reduced by a maximum of 77 percent in June, with the reduction for other months ranging from 10 to 70 percent. Low flows (those exceeded about 85 percent of the time) will be unchanged at the project site, largely due to the operation constraints of the CCEFN. As a new reservoir without a current operating permit, the Lockhart Reservoir would likely be required to meet environmental flow requirements determined by the TCEQ default Criteria (i.e., Lyons Method) or by site-specific biological studies. Flows at the

[5] Blair, W.F., “The Biotic Provinces of Texas, “Tex. J. Sci. 2:93-117, 1950.

Saltwater Barrier are relatively unaffected by the project, with an expected reduction in the mean annual flows of about 2 percent

In addition to long-term impacts within the conservation pool, minor changes to existing resources situated between the conservation pool elevation and flood pool elevation could be anticipated due to occasional temporary inundation during flood events.

Plant and animal species listed by USFWS, and TPWD, as endangered or threatened with potential habitat in Caldwell County are listed in Table 4C.27-2. No protected species have been recorded in the study area, although the area may provide potential habitat to endangered or threatened species found in Caldwell County. Other protected species may use habitats in the area during migration. A survey of the reservoir site may be required prior to dam construction to determine whether populations of or potential habitats used by listed species occur in the area to be affected.

Implementation of this reservoir alternative is expected to require field surveys by qualified professionals to document vegetation/habitat types and cultural resources that may be impacted by the proposed reservoir. Where impacts to potential protected species habitat or significant cultural resources cannot be avoided, additional studies would be necessary to evaluate habitat use and/or value, or eligibility for inclusion in the National Register of Historic Places, respectively. Compensation would be required for unavoidable adverse impacts involving net losses of wetlands.

Cultural resources protection on public lands in Texas is afforded by the Antiquities Code of Texas (Title 9, Chapter 191, Texas Natural Resource Code of 1977), the National Historic Preservation Act (Pl96-515), and the Archeological and Historic Preservation Act (PL93-291). Based on the review of available records housed at the Texas Archeological Research Laboratory in Austin, five cultural resource sites appear to occur within the proposed project area. Table 4C.27-3 lists archeological sites within a one-mile corridor of the proposed project area. Considering that the owner or controller of the project will likely be a political subdivision of the State of Texas (i.e. river authority, municipality, county, etc.), they will be required to coordinate with the Texas Historical Commission regarding whether the project will affect waters of the United States or wetlands. The project sponsor will also be required to coordinate with the U.S. Army Corps of Engineers regarding impacts to cultural resources.

Table 4C.27-2
Important Species* Having Habitat or Known to Occur in Caldwell County Potentially Affected by Lockhart Reservoir

Common Name	Scientific Name	Impact Value	Multiplier Based on Status	Adjusted Impact	Summary of Habitat Preference	Listing Entity		Potential Occurrence in County
						USFWS[1]	TPWD[1]	
American Peregrine Falcon	*Falco peregrinus anatum*	0	3	0	Open country; cliffs	DL	E	Nesting/ Migrant
Arctic Peregrine Falcon	*Falco peregrinus tundrius*	0	2	0	Open country; cliffs	DL	T	Nesting/ Migrant
Bald Eagle	*Haliaeetus leucocephalus*	0	2	0	Large bodies of water with nearby resting sites	LT-PDL	T	Nesting/ Migrant
Blue Sucker	*Cycleptus elongatus*	1	2	2	Channels and flowing pools with exposed bedrock		T	Resident
Cave Myotis Bat	*Myotis velifer*	0	1	0	Colonial & cave dwelling; hibernates in limestone caves of Edwards Plateau			Resident
Guadalupe Bass	*Micropterus treculi*	1	1	1	Streams of eastern Edwards Plateau			Resident
Guadalupe Darter	*Percina sciera apristis*	1	1	1	Raceways of medium streams and rivers.			
Henslow's Sparrow	*Ammodramus henslowii*	1	1	1	Weedy fields or cut over areas; bare ground for running and walking			Nesting/ Migrant
Mountain Plover	*Charadrius montanus*	1	1	1	Shortgrass plains and fields, sandy deserts, plowed fields			Nesting/ Migrant
Plains Spotted Skunk	*Spilogale putorius interrupta*	0	1	0	Catholic; Wooded, brushy areas and tallgrass prairies			Resident
Sandhill Woolywhite	*Hymenopappus carrizoanus*	1	1	1	Endemic; Open areas in deep sands derived from Carrizo and similar Eocene formations			Resident
Spot-tailed Earless Lizard	*Holbrookia lacerata*	1	1	1	Oak-juniper woodlands and mesquite-prickly pear			Resident
Texas Garter Snake	*Thamnophis sirtalis annectens*	1	1	1	Varied, especially wet areas; bottomlands and pastures			Resident
Texas Horned Lizard	*Phrynosoma cornutum*	0	2	0	Varied, sparsely vegetated uplands		T	Resident
Timber/Canebrake Rattlesnake	*Crotalus horridus*	0	2	0	Bottomland hardwoods		T	Resident
Whooping Crane	*Grus americana*	0	3	0	Potential migrant	LE	E	Migrant
Wood Stork	*Buteo americana*	0	2	0	Prairie ponds, flooded pastures or fields; shallow standing water		T	Nesting/ Migrant

Texas Parks and Wildlife Department (TPWD), Unpublished 2005, March 2005, Data and Map Files of the Wildlife Science Research and Diversity Division maintained by TPWD, Austin, Texas.

* LE/LT=Federally Listed Endangered/Threatened E/SA, T/SA=Federally Listed Endangered/Threatened by Similarity of Appearance

C1=Federal Candidate for Listing DL, PDL=Federally Delisted/Proposed for Delisting NL=not Federally Listed E, T=State Listed Endangered/Threatened

PE, PT=Federally Proposed Endangered/ Threatened Blank = Rare, but no regulatory listing status

Table 4C.27-3.
Previously Recorded Sites within One-mile Distance from the Proposed Lockhart Reservoir, Pipeline, and WTP

Sites	41CW19
	41CW67
	41CW73
	41CW89
	41CW90

4C.27.4 Engineering and Costing

The cost estimate for this water management strategy is shown in Table 4C.27-4. The portion of the estimate pertaining to the dam and reservoir is based on a previous cost estimate performed by the United States Study Commission in 1960,[6] subsequent to the Forrest and Cotton study. Included in the costs are a raw water intake and pump station, a 2-mile, 16-inch transmission pipeline, and a water treatment plant. Depending upon the location(s) and type(s) of use for water supplies associated with Lockhart Reservoir, additional facilities and costs could include additional pipelines to customers. Inundated land and mitigation land acquisition, and operation and maintenance costs were developed in accordance with the standard cost estimating procedures summarized in Appendix A. Costs include land purchased within the spillway design flood pool (elevation 502 ft-msl; 5,430 acres). Financing the dam for 40 years at 6 percent interest and other facilities for 30 years at 6 percent interest results in an annual expense of $4,743,000. Annual operation and maintenance costs total $1,123,000. The annual cost, including debt service and operation and maintenance, totals $5,866,000. For an annual firm yield of 5,627 acft, the resulting unit cost of treated water is $1,042 per acft (Table 4C.37-4).

[6] United States Study Commission – Texas, "Capacity Cost Curve for Lockhart Reservoir Site," May 1960.

Table 4C.27-4
Cost Estimate Summary for Lockhart Reservoir
Second Quarter 2002 Prices

Item	*Estimated Costs for Facilities*
Capital Costs	
Dam and Reservoir (Conservation Pool 50,000 acft, 2910 acres, 482 ft. msl)	$18,568,000
Intake and Pump Station (5.26 MGD)	$1,236,000
Transmission Pipeline (16 in dia., 2 miles)	$540,000
Water Treatment Plant (5.26 MGD)	$8,124,000
Distribution	$6,980,000
Total Capital Cost	**$35,448,000**
Engineering, Legal Costs and Contingencies	$12,380,000
Environmental & Archaeology Studies and Mitigation	$7,697,000
Land Acquisition and Surveying (2,921 acres)	$7,860,000
Interest During Construction (3 years)	$5,776,000
Total Project Cost	**$69,161,000**
Annual Costs	
Debt Service (6 percent, 30 years)	$1,729,000
Reservoir Debt Service (6 percent, 40 years)	$3,014,000
Operation and Maintenance	
Intake, Pipeline, Pump Station	$106,000
Dam and Reservoir	$279,000
Water Treatment Plant	$638,000
Pumping Energy Costs (1,673,028 kW-hr @ 0.06 $/kW-hr)	$100,000
Total Annual Cost	**$5,866,000**
Available Project Yield (acft/yr)	5,627
Annual Cost of Water ($ per acft)	$1,042
Annual Cost of Water ($ per 1,000 gallons)	$3.20

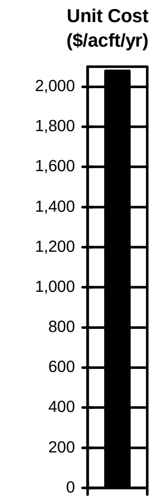
4C.27.5 Implementation Issues

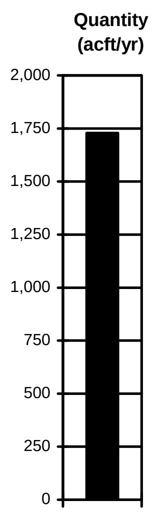
An institutional arrangement may be needed to implement this project including financing on a regional basis.

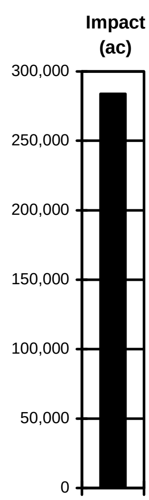
1. It will be necessary to obtain these permits:
   a. TCEQ Water Right and Storage permits.
   b. TCEQ Interbasin Transfer approval depending upon location(s) of use.
   c. USACE Sections 10 and 404 dredge and fill permits for the reservoir and pipelines.
   d. GLO Sand and Gravel Removal permits.
   e. GLO Easement for use of state-owned land.
   f. Coastal Coordination Council review.
   g. TPWD Sand, Gravel, and Marl permit.
2. Permitting, at a minimum, will require these studies:
   a. Assessment of instream flow and bay and estuary inflow changes.
   b. Habitat mitigation plan.
   c. Environmental studies.
   d. Cultural resources.
3. Land will need to be acquired through either negotiations or condemnation.
4. Relocations for the reservoir may include:
   a. County roads.
   b. Utilities.
   c. Structures of historical significance.
   d. Cemeteries.

(This page intentionally left blank.)

2006 South Central Texas Regional Water Plan
Water Management Strategy Summary Sheet







Name:* *Brush Management - Nueces Recharge Basin

Description: Selective removal of brush from rangeland watersheds in counties of the South Central Texas Water Planning Region located in the Nueces Recharge Basin that contribute recharge and thereby increase sustained yield of the Edwards Aquifer.

***Decade Needed*:** 2010 – 2060

Cost, Quantity of Water, and Land Impacted

Unit Cost of Water:	**2,080**	**$/acft/yr**	**Increase in Sustained Yield from Edwards Aquifer**
Quantity of Water:	**1,728**	**acft/yr**	**Reliability = Firm**
Land Impacted:	**284,000**	**acres**	

Additional Considerations per Regional Water Planning Guidelines

Environmental Factors: May increase runoff and instream flows. Brush management may adversely impact existing wildlife population. Chemical brush control methods may result in residual chemicals in aquifers and streams.

Impacts on Water Resources: Benefit to Edwards Aquifer water resources due to increased water for recharge. No apparent negative impacts on other water resources.

Impacts on Agricultural & Natural Resources: Potential threats to wildlife habitat due to removal of brush

Other Relevant Factors per SCTRWPG: Additional water supply and costs are only applicable to increased sustained yield of the Edwards Aquifer and the Nueces and Blanco Recharge Basins. Costs and additional water supply would be different for other aquifer systems and watersheds.

Comparison of Strategies to Meet Needs: High unit costs. No conflicts with other recommended water management strategies.

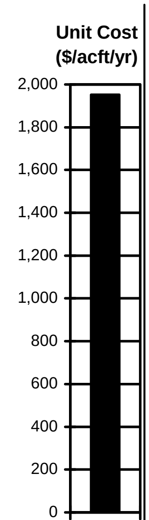
Interbasin Transfer Issues: Not applicable.

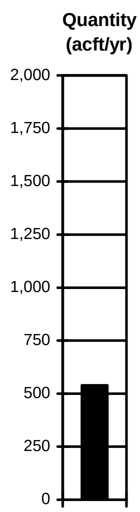
Third-Party Impacts of Voluntary Transfers: Not applicable

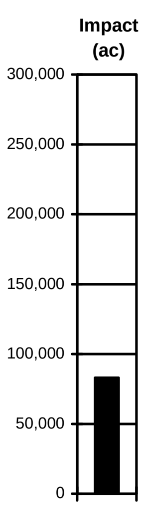
Regional Efficiency: Effective implementation of brush management strategy requires coordination and participation by many local land owners.

Water Quality Considerations: Chemical brush control methods may result in residual chemicals to aquifers and streams

2006 South Central Texas Regional Water Plan
Water Management Strategy Summary Sheet







Name:* *Brush Management - Blanco Recharge Basin

Description: Selective removal of brush from rangeland watersheds in counties of the South Central Texas Water Planning Region located in the Blanco Recharge Basin that contribute recharge and thereby increase sustained yield of the Edwards Aquifer.
***Decade Needed*:** 2010 – 2060

Cost, Quantity of Water, and Land Impacted

Unit Cost of Water:	**1,952**	**$/acft/yr**	**Increase in Sustained Yield from Edwards Aquifer**
Quantity of Water:	**540**	**acft/yr**	**Reliability = Firm**
Land Impacted:	**83,000**	**acres**	

Additional Considerations per Regional Water Planning Guidelines

Environmental Factors: May increase runoff and instream flows. Brush management may adversely impact existing wildlife population. Chemical brush control methods may result in residual chemicals in aquifers and streams.

Impacts on Water Resources: Benefit to Edwards Aquifer water resources due to increased water for recharge. No apparent negative impacts on other water resources.

Impacts on Agricultural & Natural Resources: Potential threats to wildlife habitat due to removal of brush

Other Relevant Factors per SCTRWPG: Additional water supply and costs are only applicable to increased sustained yield of the Edwards Aquifer and the Nueces and Blanco Recharge Basins. Costs and additional water supply would be different for other aquifer systems and watersheds.

Comparison of Strategies to Meet Needs: High unit costs. No conflicts with other recommended water management strategies.

Interbasin Transfer Issues: Not applicable.

Third-Party Impacts of Voluntary Transfers: Not applicable

Regional Efficiency: : Effective implementation of brush management strategy requires coordination and participation by many local land owners.

Water Quality Considerations: Chemical brush control methods may result in residual chemicals to aquifers and streams

4C.28 Brush Management

4C.28.1 Description of Brush Management for Increasing the Yield of Water Supplies

The interest in brush management as a means to increase water supply has its roots in (1) the observation that Texas rangelands changed after settlement and use by Europeans from predominantly open grasslands to increasing domination of brush, and (2) the significantly greater interception of water by brush than grasses. The former suggests that the "natural" character of Texas rangelands would be grasslands. The latter suggests the possibility of increasing aquifer recharge and streamflow by controlling and limiting growth of brush and trees in areas where grasslands would have naturally dominated. For this brush management option, brush management methods will be described, and estimates of cost and potential water supply effects will be presented.

Documentation of early European settlers[1] described Texas rangelands as grasslands. Prior to settlement by Europeans, with its associated grazing, significant brush growth was inhibited due to several natural conditions. Tree seeds commonly die following germination in grass cover because they cannot compete with grasses for sunlight and moisture. Also, any surviving seedlings are typically destroyed in periodic wildfires that occur in natural grasslands. Heavy grazing lessens the competitiveness of grass relative to brush and removes the fuel (grass) from rangeland wildfires. The result of heavy grazing is the increased dominance of trees and brush in grasslands.[2] This pattern of vegetation was common worldwide with the advent of European settlement of rangelands.[3]

In view of the consequences of heavy grazing on rangelands, ranchers have a compelling interest in controlling brush (i.e., the livestock-carrying capacity of rangeland is reduced by large increases in woody cover).[4] The effect on livestock-carrying capacity results from the noxious-tasting seedlings common in Texas, like juniper and mesquite. Livestock avoid grazing these plants and, thus, provide these brush species a competitive advantage over the grasses preferred

---

[1] Smiens, F., S. Fuhlendorf, and C. Tayor, Jr., "Environmental and Land Use Changes: A Long-Term Perspective," Juniper Symposium Proceedings, Texas A & M Agricultural Experiment Station, Sonora, Texas, 1997.
[2] Thurow, T. L., "Assessment of Brush Management as a Strategy for Enhancing Water Yield," Proceedings of the 25th Water for Texas Conference, Texas Water Resources Institute, Texas A & M University, 1998.
[3] Archer, S., "Woody Plant Encroachment into Southwestern Grasslands and Savannas: Rates, Pattern and Proximate Causes," Ecological Implications of Livestock Herbivory in the West, M. Vavra, W. Laycock, and R. Piper (editors), Society for Range Management, Denver, Co, 1994.
[4] Redecker, E. J., "The Effects of Vegetation on the Water Balance of an Edwards Plateau Watershed: A GIS Modeling Approach," M.S. Thesis, Texas A & M University, 1998.

by livestock. For a unit grazing area, fewer livestock can be supported as the percentage of brush increases. This suggests there would be some economic incentive for ranchers to control brush and, to the extent that reductions in brush cover on rangeland results in larger quantities of recharge to aquifers and run-off to streams, brush control may result in increased water supplies for municipal, industrial, irrigation and other uses.

Brush management is one of many land management practices, collectively referred to as "voluntary land stewardship", that can provide water supply at its origin. Voluntary land stewardship includes (but is not limited to) absorbing rainfall, reducing run-off, using prescribed fire properly, planning and managing grazing, brush management, managing erosion, wildlife and habitat management, and protecting springs and creek banks. With an optimal, voluntary land stewardship program, floods are reduced, aquifers are replenished, and water is released more slowly and steadily into streams, rivers, lakes and bays.[5] Although this water management strategy specifically addresses supplies attributable to brush management, additional water supply benefits, including additional inflow to reservoir systems, may be achieved with a comprehensive land stewardship program.

More problematic for brush control, however, is the evidence that more Texas ranches are being purchased for reasons other than grazing.[6] A survey of the Edwards Plateau[7] found that ranch owners who are not dependent on livestock income are less interested in investing in brush control. Some within this group of ranchers may practice brush control, but they do so for reasons other than agricultural economics.

According to previous studies, brush management may have detrimental effects on certain types of wildlife. Brush species constitute a significant portion (>58 percent) of nutritious forage for white tailed deer, and provide shelter and hiding cover for wildlife. In 1996, hunting and wildlife watching contributed approximately $2.6 billion to the Texas economy. Hunting is popular in South Texas. Previous studies recommend maintaining 40 to 60 percent brush to provide good deer habitat.[8] Consequently, it may provide greater regional benefits to leave more untreated brush to maintain diversity essential to good wildlife habitat and hunting.

[5] Letter from Texas Wildlife Association.
[6] Rowen, R. C., "Are Small-Acreage Livestock Producers Real Ranchers?," Rangelands 16:161-166, 1994.
[7] Garriga, M. D., "Tradeoffs Associated with Increasing Water Yield from the Edwards Plateau, Texas: Balancing Private Costs and Public Benefits," M.S. Thesis, Texas A & M University, 1998.
[8] Lyons, Robert K. and Tim F. Ginnett, "Integrating Deer, Quail, and Turkey Habitat: Brush Management Effects on Deer Habitat", Texas Agricultural Extension Service E-98, September 2001.

4C.28.2 Potential Water Availability

In terms of water supply, yield is the quantity of water available in a year for municipal, industrial, agricultural, and other uses. Firm yield is the quantity of water available during a critical drought. From the water supply perspective, yield is expressed as acft/yr. However, increasing the quantity of water that is not intercepted by brush on rangelands does not necessarily increase yield as defined by water supply. This is because there are other factors that could prevent this water from being available. For example, the water could enter the soil as deep percolation. It could also be captured in a rangeland impoundment.

A water balance is used to estimate the runoff and/or deep percolation from rangeland. The water balance is described in the following equation,[9]

Runoff + Deep Percolation = Precipitation – Evapotranspiration

and its variables are defined as follows:

Runoff is water that leaves the watershed through surface flow;

Deep Percolation is water that leaves the watershed by percolating through soil absent of roots; and

Evapotranspiration is water vapor entering the atmosphere through both leaf tissue and the drying of wet soil.

According to the water balance, runoff and/or deep percolation can be increased by decreasing evapotranspiration, which can be accomplished by managing vegetation. There are large differences in interception loss (water in the canopy that can be evaporated) among the common brush (post and live oak, mesquite, and juniper) and grasses. Interception losses in Texas range from 14 percent for grass to 46 percent for live oak and 73 percent for juniper.[10] Thus, a strategy of limiting brush cover and increasing grass cover would presumably increase runoff and/or deep percolation.

According to correspondence with USGS, lower zone evapotranspiration (LZETP), an index to the density of deep rooted vegetation, varies monthly based on vegetative cover, with slightly higher evapotranspiration for Juniper species and grasses. Grasses have a broader range

---

[9] Thurow, T.L., Op. Cit., 1998.
[10] Thurow, T. L. and Hester, J. W., "How an Increase in Juniper Cover Alters Rangeland Hydrology," Proceedings Juniper Symposium, Texas A & M Agricultural Experiment Station Technical Report 97-1, 1997.

of LZETP seasonal increase from 0.1 in January to 0.8 from May-September than juniper species, which ranges from 0.3 in January to 0.7 in May as shown in Table 4C.28-1.

In addition to distinctly different LZETP trends based on types of vegetation, the water use of various trees, brush, and grasses, measured using an interception storage capacity (CEPSC) parameter, has been studied by the USGS and simulated in hydrologic programs (specifically Hydrologic Simulation Program- Fortran) (phone conversation Darwin Ockerman, USGS). Interception storage is a function of cover density and is best estimated with vegetation and land use cover distribution maps. Interception values vary according to types of land coverage as shown in Table 4C.28-2.

The seasonal water use differences among trees, brush, and grasses common to the Edwards Plateau and northern Rio Grande Plains is demonstrated in Table 4C.28-3. The average unit water consumption for mesquite and Ashe Juniper is more than twice the average of the common grasses in the region. Also notable is the impact of goat grazing (biological brush control) on water consumption. At the Sonora Research Station, there were 309 Ashe Juniper trees per acre in an ungrazed enclosure and 114 per acre in a nearby pasture having a history of grazing by Angora goats.[11] Converting these densities to leaf area in order to calculate the transpiration rate, it was determined that water use in the ungrazed tract was 1.12 acft/acre and only 0.28 acft/acre in the grazed tract for the growing season period, approximately April through September.[12]

In 2002, a study was conducted by HDR to evaluate effects of brush management on runoff to determine if a relationship exists between increased runoff and firm yield. The study concluded that while brush control resulted in increased streamflow for the Nueces Watershed (downstream of the USGS Uvalde gage), this enhanced streamflow did not increase firm yield or dependable water supply available during a drought of record.

For the 2006 Plan, the South Central Texas Region Water Planning Group (SCTRWPG) requested a more detailed analysis of a long-term brush management program, with an emphasis on recharge enhancement to the Edwards Aquifer. This effort included application of Pilot Recharge Models of the Nueces and Blanco River Basins (HDR, 2002) to quantify increases

---

[11] Smiens, F., "Ashe Juniper: Consumer of Edwards Plateau Rangeland," Grazing Management Field Day, Sonora, Technical Report 90-1, Pages 17-21, 1990.
[12] Owens, M.K. and R.W. Knight, "Water Use on Rangelands," Water for South Texas, The Texas Agricultural Experiment Station, Pages 1-13, October 1992.

Table 4C.28-1.
Monthly Lower Zone Evapotranspiration Parameter (LZETP) Parameters

USGS Land Classification[1]	***Previous Land Cover[2]***	***Jan***	***Feb***	***Mar***	***Apr***	***May***	***Jun***	***Jul***	***Aug***	***Sep***	***Oct***	***Nov***	***Dec***	***Avg***
Barren Transition	*Bare exposed ground*	0	0	0	0.1	0.1	0.1	0.1	0.1	0.1	0	0	0	0.05
Cropland Pasture	*Pasture*	0.1	0.1	0.3	0.7	0.8	0.9	0.9	0.9	0.8	0.4	0.3	0.1	0.53
Deciduous Forest	*Oak-Juniper, light*	0.3	0.3	0.5	0.5	0.6	0.7	0.7	0.7	0.7	0.6	0.4	0.3	0.53
Evergreen Forest	*Juniper-Oak, moderate*	0.3	03	0.4	0.6	0.7	0.7	0.7	0.7	0.7	0.6	0.4	0.3	0.53
Herbaceous Range	*Shortgrass prarie*	0.1	0.1	0.3	0.7	0.8	0.8	0.8	0.8	0.8	0.4	0.3	0.1	0.50
Mixed Forest	*Mixed woodland*	0.1	0.1	0.3	0.6	0.6	0.7	0.7	0.7	0.6	0.5	0.3	0.2	0.46
Mixed Rangeland	*Shortgrass prarie*	0.1	0.1	0.3	0.7	0.8	0.8	0.8	0.8	0.8	0.4	0.3	0.1	0.50
Mixed Urban	*Lawns*	0.1	0.1	0.3	0.7	0.8	0.9	0.0	0.9	0.8	0.4	0.3	0.1	0.53
Other Agriculture	*Cultivated land*	0	0	0.2	0.6	0.8	0.9	0.9	0.6	0.4	0.3	0.1	0	0.40
Other Urban	*Lawns*	0.1	0.1	0.3	0.7	0.8	0.9	0.9	0.9	0.8	0.4	0.3	0.1	0.53
Residential	*Lawns*	0.1	0.1	0.3	0.7	0.8	0.9	0.9	0.9	0.8	0.4	0.3	0.1	0.53
Shrub and Brush	*Shrubland*	0.1	0.2	0.3	0.6	0.8	0.8	0.8	0.8	0.8	0.4	0.3	0.1	0.50
Strip Mine Quarry	*Rocky slopes*	0.1	0.1	0.2	0.3	0.3	0.3	0.3	0.3	0.3	0.2	0.1	0.1	0.22

[1] USGS, "Land Use and Land Cover Digital Data from 1:250,000 Scale Maps," Earth Science Information Center, Reston, Virginia, 1986.

[2] USGS, Upper Cibolo Creek Watershed Model (written communication, 2004).

USGS, Upper Cibolo Creek Watershed Model (written communication, 2004).

Table 4C.28-2.
Interception Values for Various Land Covers

USGS Land Classification[1]	Pervious Land Cover[2]	Interception (in)
Barren Transition	*Bare exposed ground*	0.05
Cropland Pasture	*Pasture*	0.12
Deciduous Forest	*Oak, Juniper, light*	0.3
Evergreen Forest	*Juniper- Oak, Moderate*	0.4
Herbaceous Range	*Shortgrass prairie*	0.15
Mixed Forest	*Mixed woodland*	0.15
Mixed Rangeland	*Shortgrass prairie*	0.15
Mixed Urban	*Lawns*	0.12
Other Agriculture	*Cultivated Land*	0.1
Other Urban	*Lawns*	0.12
Residential	*Lawns*	0.12
Shrub and Brush	*Shrubland*	0.12
Strip Mine Quarries	*Rocky slopes*	0.1

[1] USGS, "Land Use and Land Cover Digital Data from 1:250,000 Scale Maps," Earth Science Information Center, Reston, Virginia, 1986.
[2] USGS, Upper Cibolo Creek Watershed Model (written communication, 2004).

Table 4C.28-3.
Densities and Seasonal Water Use for Common Plant Species

Species	Density	Seasonal Water Use[1] (acft)
Mesquite	307 plants/acre	0.93
Juniper (no grazing)	309 plants/acre	1.12
Juniper (goat grazing)	114 plants/acre	0.28
Oak	50 plants/acre	0.96
Sideoats grama grass	890 lbs./acre	0.20
Kleingrass	1,525 lbs./acre	0.59
Buffalograss	1,340 lbs./acre	0.53

[1]The growing season of April through September.

Source: (Owens and Knight, 1992)

in streamflow and recharge enhancement to the Edwards Aquifer associated with brush management. This recharge enhancement information was then processed by an Edwards Aquifer model (GWSIM4) to quantify potential increases in sustained yield. GWSIM4 Edwards Aquifer groundwater flow model developed by the Texas Water Development Board simulates

Edwards aquifer response in terms of water levels and springflows for specified recharge and pumping rates.

4C.28.2.1 Using Hydrologic Simulation Program Fortran to Simulate Brush Management

4C.28.2.1.1 Introduction

HDR conducted a study in June 2002 on behalf of the Edwards Aquifer Authority to develop Pilot Recharge Models of the Nueces and Blanco River Basins (HDR, 2002) to provide accurate daily recharge data to the Edwards Aquifer with sufficient accuracy to model enhanced recharge associated with new recharge dams, precipitation enhancement (weather modification), and brush management initiatives. The Pilot Recharge Models for the Nueces and Blanco River Basins used the Hydrologic Simulation Program-Fortran (HSPF) Release 11 to calculate daily recharge to the Edwards Aquifer. The pilot recharge models of the Nueces and Blanco Recharge Basins use hydraulic and hydrologic routines within HSPF to translate daily streamflow, rainfall, and evaporation into recharge and downstream flow by simulation of interception, overland flow, infiltration, evapotranspiration, shallow storage, deep percolation, and other hydrologic processes.[13]

The 2002 Pilot Recharge Models included for the Nueces Recharge Basin, eight land segments subdivided on the basis of geologic characteristics and observed streamflow loss rates and seven river reaches defined in accordance with an intensive streamflow loss survey conducted by the USGS (HDR, 2002). The Blanco Recharge Basin included seven land segments and six river reaches (with additional reaches representative of seven existing flood retardation structures that serve to enhance Edwards Aquifer recharge) created according to the same method used for the Nueces Basin. While the model works very well for estimating recharge based on historical conditions, since it was calibrated with a USGS gage on the upstream side of the recharge zone for both Nueces and Blanco Basins, it did not simulate the hydrology of the contributing zone upstream of the recharge zone. In order to include contributions from the drainage areas upstream of the recharge zone, it was necessary to modify the HSPF Pilot Recharge Models. The model modifications are described below.

[13] Edwards Aquifer Authority, Pilot Recharge Models of the Nueces and Blanco River Basins, June, 2002.

4C.28.2.1.2 Baseline Conditions

To more accurately reflect baseline conditions and brush management for the Blanco and Nueces Basins, the HSPF Pilot Recharge Models were modified in the following ways:

- Land segments were added upstream of the Nueces Recharge Basin (LS 401 & LS 402) and Blanco Recharge Basin (LS 401) to simulate upstream Blanco and Nueces watersheds contributing to the recharge zone(s). The Nueces Recharge Basin and Blanco Recharge Basin are shown in Figure 4C.28-1 and 4C.28-2, respectively.
- The Nueces River Basin period of record was extended from 1950 through 1998 to 1934 through 1998. Similarly, the Blanco River Basin historical simulation period of record was extended from 1956 through 1998 to 1934 through 1998. These adjustments were made to include, in the model simulation, the drought of record which occurred in the 1950's.
- The model parameter associated with LZETP was changed from an annual average to a monthly distribution to account for seasonal evapotranspiration variations.

Daily precipitation gage data were obtained from the National Weather Service (NWS), Edwards Aquifer Authority (EAA), and the USGS. The active precipitation stations used in the Pilot Study were used to extend the period of record for the Nueces River Basin (previously 1950-1998) and Blanco River Basin (previously 1956-1998) to include 1934-1998. For new land segments (two in Nueces River Basin and one in Blanco River Basin), the nearest active precipitation stations to the new land segments were used for daily precipitation data.

Monthly gross water surface evaporation rates were obtained from the Texas Water Development Board (TWDB) for one degree quadrangles representative of the Nueces and Blanco Recharge Basins for January 1934 through December 1998 for the two new land segments in Nueces River Basin and one new segment in the Blanco River Basin. For land segments contained in the original Pilot Models, the period of record was extended to January 1934. The procedure used to apply monthly evaporation quadrangle data to land segments was based on an inverse relationship of distance from the center of the land segment to center of the evaporation quadrangle.

The Pilot Model contained average annual values for LZETP. Due to the high variability in monthly evapotranspiration rates described earlier in this section, the HSPF model was modified to reflect monthly LZETP values rather than annual average LZETP values. Land use

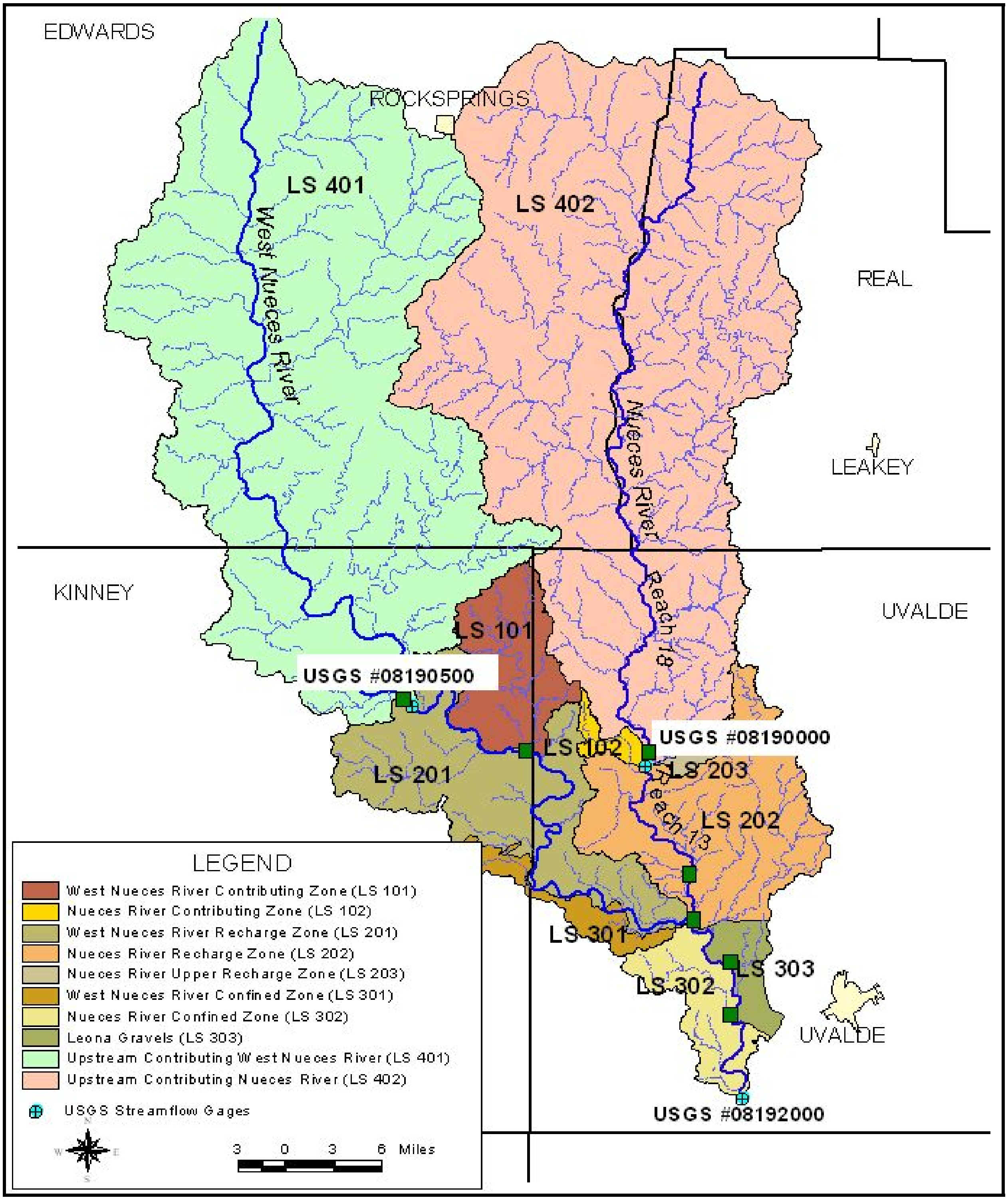


Figure 4C.28-1. Land Segments and River Reaches in the Nueces Recharge Basin

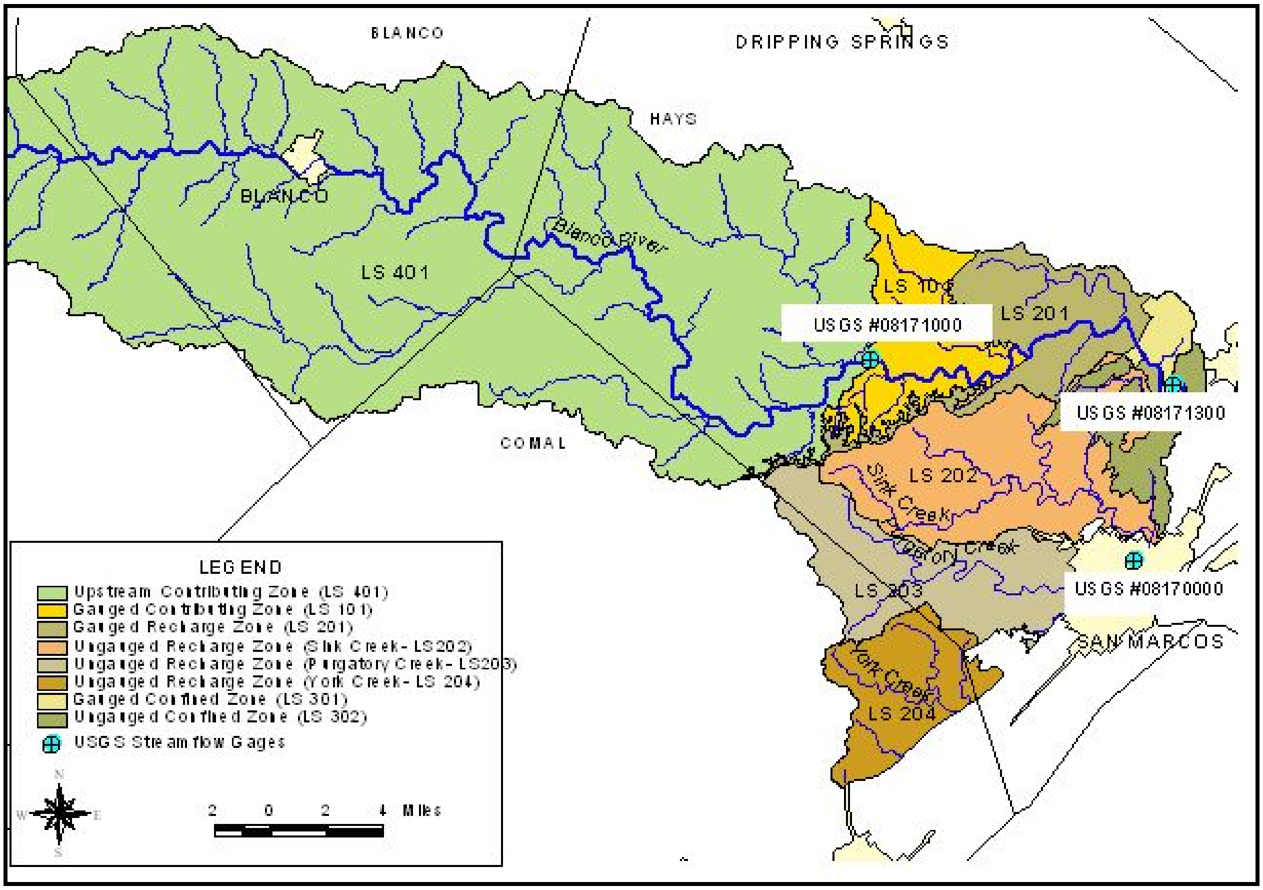


Figure 4C.28-2. Land Segments and River Reaches in the Blanco Recharge Basin

data for the Nueces and Blanco Recharge Basins, created by the USGS in 1986 and obtained from the Texas Natural Resource Information System (TNRIS), was used to determine the amount of land cover types in the basin (based on percentage of total basin).

The percentage of land in each vegetative category was then multiplied by LZETP monthly values for each vegetative category (based on Table 4C.28-1). This monthly "calculated" LZETP was then used to convert "calibrated" annual average LZETP to monthly values for each land segment in the Nueces Basin and Blanco Basin as shown in Table 4C.28-4 and Table 4C.28-5, respectively.

Precipitation and evaporation files values were updated for the entire period of record (1934-1998), LZETP values were revised on a monthly basis, and new land segments with associated streams were added for upstream contributing zones and calibrated using historical USGS streamflow gage data. The upstream contributing zones for the Nueces Recharge Basin used USGS Gage #08190500 (West Nueces at Bracketville) for Land Segment 401 and USGS

Gage #08190000 (Nueces at Laguna) for Land Segment 402 for calibration. For the Blanco Basin, LS 401 (Upstream Contributing) was calibrated using historical data for USGS Gage #08171000 (Blanco River at Wimberley). Detailed calibration procedures and results are included in Appendix D. The new contributing zones for the Nueces and Blanco Basins were well calibrated to evaluate brush management effects on recharge (Appendix D).

Table 4C.28-4.
Monthly LZETP Values for Nueces Recharge Basin, HSPF Model

Land Segment	Calculated Monthly												Avg
	Jan	Feb	Mar	Apr	May	Jun	July	Aug	Sept	Oct	Nov	Dec	
101	0.19	0.19	0.27	0.43	0.50	0.50	0.50	0.50	0.50	0.40	0.27	0.19	0.37
102	0.08	0.12	0.17	0.32	0.41	0.41	0.41	0.41	0.41	0.24	0.17	0.08	0.27
201	0.10	0.13	0.18	0.33	0.41	0.42	0.42	0.42	0.41	0.26	0.18	0.10	0.28
202	0.09	0.12	0.18	0.33	0.42	0.42	0.42	0.42	0.42	0.26	0.18	0.09	0.28
203	0.09	0.13	0.18	0.33	0.42	0.42	0.42	0.42	0.42	0.26	0.18	0.09	0.28
301	0.04	0.08	0.12	0.24	0.32	0.32	0.32	0.32	0.32	0.16	0.12	0.04	0.2
302	0.05	0.08	0.13	0.27	0.35	0.35	0.35	0.35	0.35	0.18	0.13	0.05	0.22
303	0.05	0.07	0.14	0.30	0.36	0.38	0.38	0.38	0.36	0.18	0.14	0.05	0.23
401*	0.15	0.16	0.22	0.34	0.41	0.41	0.41	0.41	0.41	0.32	0.22	0.15	0.3
402*	0.14	0.15	0.21	0.35	0.41	0.41	0.41	0.41	0.41	0.31	0.21	0.14	0.3
*Average LZETP values for LS 401 and LS 402 (0.30) based on evaluated land coverage.													

Table 4C.28-5.
Monthly LZETP Values for Blanco Recharge Basin, HSPF Model

Land Segment	Calculated Monthly												Avg
	Jan	Feb	Mar	Apr	May	Jun	July	Aug	Sept	Oct	Nov	Dec	
101	0.15	0.15	0.21	0.35	0.41	0.41	0.41	0.41	0.41	0.32	0.21	0.15	0.30
201	0.12	0.13	0.21	0.36	0.41	0.43	0.43	0.43	0.42	0.31	0.21	0.13	0.30
202	0.14	0.15	0.23	0.34	0.40	0.42	0.42	0.42	0.41	0.32	0.22	0.15	0.30
203	0.15	0.15	0.23	0.34	0.40	0.41	0.41	0.41	0.41	0.32	0.22	0.15	0.30
204	0.16	0.16	0.22	0.35	0.40	0.40	0.40	0.40	0.40	0.33	0.22	0.16	0.30
301	0.10	0.11	0.22	0.36	0.42	0.46	0.46	0.46	0.44	0.28	0.20	0.11	0.30
302	0.13	0.14	0.24	0.33	0.38	0.43	0.43	0.43	0.41	0.32	0.21	0.14	0.30
401*	0.15	0.15	0.21	0.35	0.41	0.42	0.42	0.42	0.41	0.32	0.21	0.15	0.30
* Average LZETP value (0.30) based on similar land coverage for surrounding land segments.													

4C.28.2.1.3 Baseline + Brush Management Conditions

According to Hibbert (1979), for brush management to increase water supplies the following conditions should be met: (1) annual precipitation must be greater than 18 inches, (2) brush removed must have been replaced with grasses that use less water, and (3) replacement species must be shallow-rooted, deciduous, or have low biomass. According to calculated precipitation values based on NWS gauged data, the Nueces and Blanco Recharge Basins receive 25.7 and 34.5 inches of rain, respectively. Therefore, the precipitation condition is met, and the other two conditions are discussed below.

After calibrating the upstream contributing land segments for the Nueces Recharge Basin (LS 401 & 402) and Blanco Recharge Basin (LS 401), adjustments were made to Lower Zone Evapotranspiration Parameters (LZETP) and Interception Storage Coefficient Values (CEPSC) to quantify the impacts of brush management. Based on a phone conversation with Phillip Wright (USDA) and Region L staff workgroup recommendation, a brush management program could reasonably expect 35% land area participation with 50% brush removal. To simulate brush management in HSPF, it was assumed that 35% of each land segment area defined as evergreen forest (i.e. Ashe Juniper and other brush species) by USGS land use data would be converted to Mixed Rangeland.

After the percentage of land for evergreen forest and mixed rangeland areas were adjusted to account for brush management, the new monthly LZETP values were calculated and values compared for baseline and brush management conditions. Land segments that contained evergreen forests for the baseline showed a decrease in LZETP, while land segments with no evergreen forests had no change in LZETP. The monthly LZETP values that were used to simulate brush management in the HSPF models are shown in Table 4C.28-6 for the Nueces Basin and Table 4C.28-7 for the Blanco Basin.

The changes in calculated monthly LZETP with brush management for the Blanco Recharge Basin and Nueces Recharge Basin vary monthly and have different seasonal trends. During the fall/winter months (October-March), brush management decreases evapotranspiration (Table 4C.28-8 and Table 4C.28-9). In the spring/summer months (April-September), however, evapotranspiration increases with brush management. This means that by replacing evergreen forests (i.e. Ashe Juniper) with grasses and other vegetative species, less evapotranspiration

Table 4C.28-6.
Monthly LZETP Values (with Brush Management) for
Nueces Recharge Basin, HSPF Model

Land Segment	Calculated Monthly												Avg
	Jan	Feb	Mar	Apr	May	Jun	July	Aug	Sept	Oct	Nov	Dec	
101	0.15	0.15	0.25	0.45	0.52	0.52	0.52	0.52	0.52	0.36	0.25	0.15	0.36
102	0.07	0.11	0.17	0.33	0.41	0.42	0.42	0.42	0.41	0.23	0.17	0.07	0.27
201	0.08	0.11	0.18	0.34	0.42	0.42	0.42	0.42	0.42	0.25	0.18	0.08	0.28
202	0.08	0.11	0.18	0.34	0.43	0.43	0.43	0.43	0.43	0.24	0.18	0.08	0.28
203	0.08	0.11	0.18	0.34	0.43	0.43	0.43	0.43	0.43	0.24	0.18	0.08	0.28
301	0.04	0.08	0.12	0.24	0.32	0.32	0.32	0.32	0.32	0.16	0.12	0.04	0.20
302	0.04	0.08	0.13	0.27	0.35	0.35	0.35	0.35	0.35	0.18	0.13	0.05	0.22
303	0.05	0.07	0.14	0.30	0.36	0.38	0.38	0.38	0.36	0.18	0.14	0.05	0.23
401	0.12	0.13	0.20	0.36	0.43	0.43	0.43	0.43	0.43	0.29	0.20	0.12	0.29
402	0.11	0.12	0.20	0.36	0.43	0.43	0.43	0.43	0.43	0.28	0.20	0.11	0.29

Table 4C.28-7.
Monthly LZETP Values (with Brush Management) for
Blanco Recharge Basin, HSPF Model

Land Segment	Calculated Monthly												Avg
	Jan	Feb	Mar	Apr	May	Jun	July	Aug	Sept	Oct	Nov	Dec	
101	0.11	0.12	0.20	0.36	0.43	0.43	0.43	0.43	0.43	0.29	0.20	0.11	0.29
201	0.10	0.12	0.21	0.37	0.42	0.44	0.44	0.44	0.42	0.30	0.20	0.12	0.30
202	0.12	0.13	0.22	0.35	0.41	0.43	0.43	0.43	0.42	0.30	0.20	0.13	0.30
203	0.12	0.12	0.21	0.36	0.41	0.43	0.43	0.43	0.42	0.29	0.20	0.12	0.30
204	0.12	0.12	0.20	0.36	0.42	0.42	0.42	0.42	0.42	0.29	0.20	0.12	0.29
301	0.10	0.11	0.22	0.36	0.42	0.46	0.46	0.46	0.44	0.28	0.20	0.11	0.30
302	0.13	0.14	0.24	0.34	0.38	0.43	0.43	0.43	0.41	0.31	0.21	0.14	0.30
401	0.11	0.12	0.20	0.37	0.42	0.43	0.43	0.43	0.42	0.28	0.20	0.11	0.29

Table 4C.28-8.
Change in Monthly LZETP Values (with-without Brush Management) for Nueces Recharge Basin, HSPF Model

Land Segment	Calculated Monthly (with-without Brush Management)												Avg
	Jan	Feb	Mar	Apr	May	Jun	July	Aug	Sept	Oct	Nov	Dec	
101	-0.04	-0.04	-0.02	0.02	0.02	0.02	0.02	0.02	0.02	-0.04	-0.02	-0.04	-0.01
102	-0.01	-0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-0.01	0.00	-0.01	0.00
201	-0.01	-0.01	-0.01	0.01	0.01	0.01	0.01	0.01	0.01	-0.01	-0.01	-0.01	0.00
202	-0.01	-0.01	-0.01	0.01	0.01	0.01	0.01	0.01	0.01	-0.01	-0.01	-0.01	0.00
203	-0.01	-0.01	-0.01	0.01	0.01	0.01	0.01	0.01	0.01	-0.01	-0.01	-0.01	0.00
301	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
302	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
303	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
401	-0.03	-0.03	-0.02	0.02	0.02	0.02	0.02	0.02	0.02	-0.03	-0.02	-0.03	-0.01
402	-0.03	-0.03	-0.02	0.02	0.02	0.02	0.02	0.02	0.02	-0.03	-0.02	-0.03	-0.01

Table 4C.28-9.
Change in Monthly LZETP Values (without-with Brush Management) for Blanco Recharge Basin, HSPF Model

Land Segment	Calculated Monthly (with-without brush management)												Avg
	Jan	Feb	Mar	Apr	May	Jun	July	Aug	Sept	Oct	Nov	Dec	
101	-0.03	-0.03	-0.02	0.02	0.02	0.02	0.02	0.02	0.02	-0.03	-0.02	-0.03	-0.01
201	-0.02	-0.02	-0.01	0.01	0.01	0.01	0.01	0.01	0.01	-0.02	-0.01	-0.02	0.00
202	-0.02	-0.02	-0.01	0.01	0.01	0.01	0.01	0.01	0.01	-0.02	-0.01	-0.02	0.00
203	-0.03	-0.03	-0.01	0.01	0.01	0.01	0.01	0.01	0.01	-0.03	-0.01	-0.03	0.00
204	-0.04	-0.04	-0.02	0.02	0.02	0.02	0.02	0.02	0.02	-0.04	-0.02	-0.04	-0.01
301	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
302	-0.01	-0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-0.01	0.00	-0.01	0.00
401	-0.03	-0.03	-0.02	0.02	0.02	0.02	0.02	0.02	0.02	-0.03	-0.02	-0.03	-0.01

occurs during the winter months and more evapotranspiration occurs in the summer months.

Similar to the procedure used for LZETP, the results of brush management on interception (CEPSC) parameters were simulated in HSPF by converting 35% of the land area defined as Evergreen Forest (i.e., Ashe Juniper and other brush species) to Mixed Rangeland using the CEPSC parameters listed in Table 4C.28.2 for both Blanco and Nueces Recharge Basins. Since the Evergreen Forest has a CEPSC value of 0.4 and Mixed Rangeland has a CEPSC value of 0.15 (Table 4C.28-2), the new CEPSC with brush management will be lower than without brush management. The amount of CEPSC decrease depends on the amount of evergreen forest in each land segment (i.e., land segments with more evergreen forest coverage will have a larger decrease in CEPSC than land segments with less evergreen forest). The change in CEPSC (with- without brush management) and is shown in Table 4C.28-10 for the Nueces Basin and Table 4C.28-11 for the Blanco Basin.

4C.28.2.1.4 Recharge Enhancements (Attributable to Brush Management)

After performing the HSPF simulations with and without brush management, the difference in recharge was computed to quantify the enhanced recharge to the Edwards Aquifer for Nueces and Blanco Recharge Basins. The Nueces Recharge Basin provides recharge to the Edwards Aquifer from land segments (contributing and recharge zones), and their associated reaches. Recharge to the Edwards Aquifer from the Blanco Recharge Basin occurs from land segments (contributing and recharge zones), reaches, and flood retardation structures.

Recharge data from the HSPF model were evaluated for the entire 65 year simulation (1934-1998) and 5-year drought (1952-1956) to determine the amount of enhanced recharge with brush management within land segments of the Nueces and Blanco Basins, as shown in Figures 4C.28-1 and 4C.28-2.

The Nueces Basin drought of record was from 1952 through 1956, according to NWS precipitation gage data (16.8 inches of rainfall, based on 5-year precipitation average from 1934-1998). According to HSPF model results for the 65 year model simulation (1934-1998), brush management on the watersheds shown in Figure 4C.28-1 is estimated to increase recharge in the Nueces Recharge Basin an average of 9,862 acft/yr (or 8.6% increase when compared to recharge without brush management) as shown in Table 4C.28-12. For the 5-year drought period (1952-1956), the estimated increase in Edwards Recharge in the Nueces Basin is 920 acft/yr (or 2.2 %).

The Blanco Basin drought of record was from 1952 through 1956, according to NWS precipitation gage data (25.4 inches of rainfall, based on 5-year precipitation average from 1934-1998). According to HSPF model results for the 65 year model simulation (1934-1998), brush management on the watersheds shown in Figure 4C.28-2 is estimated to increase recharge in the Blanco Recharge Basin an average of 4,815 acft/yr (a 7.3% increase when compared to recharge

Table 4C.28-10.
Interception (CEPSC) Values for Nueces Recharge Basin
(Without and With Brush Management)

Land Segment	Evergreen Forest Area (% of Land Segment) without Brush Management	CEPSC (in.) without Brush Management	CEPSC (in.) with Brush Management	Change in CEPSC	% Change
101	83.83%	0.14	0.11	-0.03	20.52%
102	26.20%	0.12	0.11	-0.01	11.85%
201	38.70%	0.12	0.10	-0.02	14.74%
202	32.89%	0.12	0.10	-0.02	13.57%
203	35.26%	0.12	0.10	-0.02	14.11%
301	0.09%	0.12	0.12	0.00	0.06%
302	1.23%	0.1	0.10	0.00	0.84%
303	0.00%	0.09	0.09	0.00	0.00%
401	80.36%	0.14	0.11	-0.03	20.34%
402	75.75%	0.14	0.11	-0.03	19.77%

Table 4C.28-11.
Interception (CEPSC) Values for Blanco Recharge Basin
(Without and With Brush Management)

Land Segment	Evergreen Forest Area (% of Land Segment) without Brush Management	CEPSC (in.) without Brush Management	CEPSC (in.) with Brush Management	Change in CEPSC	% Change
101	78.39%	0.12	0.10	-0.02	20.16%
201	38.52%	0.12	0.10	-0.02	12.84%
202	52.49%	0.13	0.11	-0.02	14.68%
203	63.05%	0.13	0.11	-0.02	16.66%
204	83.95%	0.12	0.09	-0.03	21.00%
301	0.00%	0.16	0.16	0.00	0.00%
302	17.00%	0.12	0.11	-0.01	5.80%
401	77.30%	0.12	0.10	-0.02	20.01%

Table 4C.28-12.
Summary of Nueces Basin Recharge
(with and without Brush Management)

Nueces Recharge	Baseline (without Brush Management)	Baseline + Brush Management	Change Due to Brush Management	% Change in Recharge
Average Annual Recharge acft (1934-1998)	115,063 acft	124,925 acft	9,862 acft	8.6%
Average Drought Recharge acft (1952-1956)	41,829 acft	42,749 acft	920 acft	2.2%

Table 4C.28-13.
Summary of Blanco Basin Recharge
(with and without Brush Management)

Nueces Recharge	Baseline (without Brush Management)	Baseline + Brush Management	Change Due to Brush Management	% Change in Recharge
Average Annual Recharge acft (1934-1998)	65,969 acft	70,784 acft	4,815 acft	7.3%
Average Drought Recharge acft (1952-1956)	11,877 acft	14,092 acft	2,215 acft	18.6%

without brush management) as shown in Table 4C.28-13. For the 5-year drought (1952-1956), the estimated increase in Edwards Recharge in the Blanco Basin is 2,215 acft/yr (or 7.3 %).

The monthly change in Edwards Aquifer Recharge from the updated HSPF Pilot Recharge Model of the Nueces and Blanco Recharge Basin with brush management is shown in Table 4C.28-14 and Table 4C.28-15, respectively. As shown in the tables, there are several instances when brush management decreases enhanced recharge when compared to the baseline. This mainly occurs in the summer months when more evapotranspiration occurs with brush management than without, as indicated in Tables 4C.28-8 and 4C.28.9.

The Blanco Basin receives a greater percent increase in recharge during the drought for two reasons: 1) there was more rainfall during the drought than in the Nueces Basin, and 2) the Blanco Basin has more evergreen forest over the recharge zone (52% of total land area in the Blanco Basin compared to 35% in the Nueces Basin), hence a larger opportunity for brush management during the drought. The amount of rainfall during the drought was compared to average rainfall for each basin. The Blanco Basin received 25.4 inches during the drought compared to an annual average of 34.1 inches from 1934-1998 (or 75%) whereas the Nueces Basin received 16.8 inches during the drought compared to an annual average of 25.7 inches (or

64%). Due to these phenomena, the magnitude of recharge enhancements during the drought is different for the Nueces and Blanco Basins. NWS precipitation gages located nearby were used to determine historical precipitation over land segments within the Nueces and Blanco Basins. The results of weather modification may vary with more localized precipitation gaging stations over smaller watershed areas.

4C.28.2.1.5 Increase in Sustained Yield (attributable to Brush Management)

The recharge enhancements attributable to brush management for the Nueces and Blanco Recharge Basins were processed with GWSIM4 to determine increases in sustained yield from the Edwards Aquifer (Appendix C). Sustained yield of the Edwards aquifer is defined as the amount of pumpage from the Edwards such that a simulated minimum flow at Comal Springs is protected during the drought of record (in this case, 60 cfs). The additional water supply is based on increases in sustained yield from the Edwards Aquifer. The brush management option evaluated for the Nueces and Blanco Basins is calculated to increase sustained yield by 1,728 acft/yr and 540 acft/yr, respectively. The Nueces Basin has greater water supply benefits with a brush management program due to its higher average annual recharge as compared with the Blanco Basin, even though the Blanco Basin provides greater recharge during the drought. Also, the Nueces Recharge Basin has a larger watershed area (1,200,000 acres – Figure 4C.28-1) as compared to 340,000 acres in the Blanco Basin (Figure 4C.28-2). It is emphasized, however, that these recharge estimates pertain only to the Edwards Aquifer area and are not necessarily applicable to other aquifers.

4C.28.3 Best Management Practices for Brush Control

In Texas, brush control authorization was granted in 1985 by the Legislature to the Texas State Soil and Water Conservation Board (TSSWCB). The purpose of the program is to provide "selective control, removal, or reduction of noxious brush—such as mesquite, salt cedar, or other brush species—that consume water to a degree that is detrimental to water conservation." The State Plan delineates a critical area in Texas for brush control. The counties in the area are those having 16 to 36 inches of precipitation per year. Cost of brush control would be shared between landowners and the State, with soil conservation districts determining the maximum and

Table 4C.28-14.
Change in Historical Edwards Aquifer Recharge (with-without brush management) from the HSPF Pilot Recharge Model of the Nueces Recharge Basin

Year	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	Grand Total
1934	493	165	449	544	293	269	49	527	193	120	119	1,048	4,269
1935	489	449	555	767	-3,285	-4,549	-5,172	-4,360	-4,632	-1,734	-579	723	-21,330
1936	478	805	1,342	1,008	1,928	585	-484	621	-2,976	-4,278	-4,082	-2,038	-7,091
1937	26	753	551	809	940	1,066	1,461	1,536	1,642	1,873	1,988	3,208	15,853
1938	-2,228	18	1,340	638	152	1,143	-339	833	1,179	814	949	966	5,465
1939	2,128	994	1,295	907	959	695	-3,166	-1,618	151	426	818	802	4,391
1940	1,048	1,959	789	698	112	663	241	169	134	216	799	906	7,732
1941	769	1,077	1,825	1,056	488	602	1,351	959	1,495	1,110	950	909	12,591
1942	953	983	958	1,045	934	823	994	893	957	-155	636	756	9,778
1943	860	751	805	1,003	939	1,238	799	174	1,045	929	652	1,327	10,523
1944	1,522	1,460	1,275	385	790	214	476	1,126	594	833	859	890	10,424
1945	3,080	1,146	2,109	571	771	516	475	404	425	1,295	278	260	11,330
1946	908	536	372	299	941	349	206	200	1,028	19	601	619	6,080
1947	2,209	546	854	613	377	-297	-13	304	264	260	528	435	6,079
1948	184	856	211	272	294	-78	652	263	375	277	401	240	3,947
1949	1,029	604	-404	739	245	784	623	-320	379	2,643	295	1,315	7,933
1950	419	846	405	354	299	486	453	267	346	371	193	171	4,611
1951	149	126	267	177	348	171	152	134	112	402	244	460	2,741
1952	184	1,024	427	277	290	265	207	168	150	120	140	431	3,684
1953	194	137	498	231	216	189	133	437	270	983	208	358	3,854
1954	195	156	150	102	-562	-1,897	-2,326	29	79	631	97	87	-3,259
1955	94	245	241	86	84	321	171	170	-1,543	-2,604	19	340	-2,375
1956	344	481	230	202	198	175	165	122	155	367	76	180	2,696
1957	92	384	436	598	-387	-71	282	215	604	1,891	1,219	942	6,206
1958	1,596	-1,757	398	780	336	-1,606	-2,133	170	-838	-2,596	-2,191	141	-7,700
1959	108	737	425	915	-190	-824	-3,841	-304	767	2,584	1,242	1,438	3,056
1960	1,346	1,861	1,179	933	836	842	1,270	702	773	1,487	763	1,667	13,660
1961	1,655	1,929	1,350	1,128	795	904	323	1,213	1,257	1,653	1,413	1,480	15,099
1962	1,391	1,267	826	709	743	769	716	153	79	75	92	156	6,978
1963	128	405	201	260	9	140	151	141	322	502	605	549	3,413
1964	802	934	848	478	313	277	259	271	1,015	-1,814	427	552	4,363
1965	562	2,298	792	777	566	-943	-537	377	529	507	448	1,529	6,905
1966	1,311	1,224	737	413	338	383	302	-1,037	-1,317	177	162	183	2,877
1967	179	152	150	292	159	145	131	191	1,323	1,123	358	689	4,893
1968	1,712	948	921	179	1,166	571	562	327	890	947	1,130	1,187	10,540
1969	1,629	1,063	490	515	492	278	263	535	562	3,611	6	296	9,742
1970	1,116	1,786	1,215	1,019	821	871	902	569	1,157	979	738	747	11,921
1971	516	134	162	223	153	139	-1,411	-3,073	-2,783	579	435	1,688	-3,239
1972	1,834	1,209	989	848	762	924	883	409	772	828	846	1,276	11,579
1973	1,258	2,414	1,893	1,545	1,101	532	-1,056	1,415	1,629	856	867	1,787	14,241
1974	2,375	1,790	2,003	1,480	1,474	1,312	910	1,397	1,903	2,342	2,024	3,160	22,170
1975	2,676	2,916	2,214	2,310	2,721	2,500	2,236	1,878	1,893	1,525	2,025	1,690	26,582
1976	1,500	1,068	842	2,086	973	1,352	1,134	-1,287	2,173	4,398	3,607	3,920	21,766
1977	4,971	3,957	3,957	3,144	3,383	3,171	2,665	2,648	2,381	2,609	3,456	3,031	39,372
1978	2,690	2,560	1,762	1,389	1,556	1,582	839	125	1,301	1,381	1,845	1,999	19,029
1979	1,921	2,225	1,836	1,866	1,560	2,005	2,176	1,685	1,478	1,516	1,425	1,444	21,138
1980	1,544	986	895	789	908	782	202	717	180	283	778	1,043	9,107
1981	801	523	2,109	709	868	-2,117	-1,256	1,259	1,404	-96	1,311	2,015	7,529
1982	2,145	3,351	2,420	1,748	2,022	1,605	1,492	1,490	905	886	1,077	1,725	20,865
1983	1,901	1,643	2,762	1,104	1,139	537	396	265	417	-269	313	714	10,923
1984	2,174	376	193	167	175	154	141	142	127	1,803	1,016	946	7,413
1985	1,604	612	749	640	474	460	208	312	450	1,688	1,347	1,151	9,696
1986	1,409	1,155	1,030	936	1,007	875	928	842	1,020	-263	1,256	2,870	13,064
1987	1,486	2,799	2,464	2,063	1,118	3,653	4,645	4,977	3,493	4,665	4,803	5,115	41,279
1988	4,687	3,830	3,196	2,486	1,967	1,743	1,051	1,355	1,424	1,506	1,309	1,409	25,962
1989	2,267	1,926	1,520	1,165	844	376	180	305	135	650	1,283	364	11,014
1990	572	5,083	2,021	287	-2,166	432	-713	-608	339	363	677	848	7,135
1991	1,791	1,823	1,039	426	441	368	321	285	-1,250	-1,017	226	61	4,514
1992	868	352	661	1,786	2,077	1,832	2,616	3,518	3,399	3,207	3,091	3,352	26,760
1993	4,217	4,162	4,066	3,150	2,529	2,011	1,693	1,439	1,373	1,378	1,309	1,338	28,664
1994	1,169	1,036	2,974	669	918	745	56	738	908	2,063	2,065	2,849	16,190
1995	1,618	1,357	2,097	925	931	902	549	259	649	786	1,569	960	12,603
1996	831	790	283	178	261	165	224	210	408	909	-575	704	4,387
1997	597	2,513	2,204	731	379	-710	-804	715	773	1,498	1,187	1,715	10,799
1998	1,538	1,998	1,565	825	624	142	217	-875	-2,828	1,140	2,146	2,125	8,618
Average (1934-1998)	1,263	1,291	1,176	884	676	507	250	448	508	819	851	1,189	9,862
Drought Avg (1952-1956)	202	409	309	180	45	-189	-330	185	-178	-101	108	279	920

Table 4C.28-15.
Change in Historical Edwards Aquifer Recharge (with-without brush management) from the HSPF Pilot Recharge Model of the Blanco Recharge Basin

Year	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	Grand Total
1934	1,317	582	505	753	190	35	52	49	60	38	274	1,628	5,481
1935	655	891	708	783	978	355	-45	32	380	268	277	957	6,238
1936	206	398	75	321	582	44	344	-95	248	439	665	719	3,947
1937	789	23	1,438	222	123	306	-80	13	167	173	359	1,324	4,856
1938	1,076	581	652	818	553	292	-73	0	20	25	70	61	4,077
1939	416	460	476	284	443	271	1	137	113	107	226	314	3,248
1940	477	1,051	669	737	409	281	303	54	38	276	1,879	1,147	7,320
1941	648	791	271	1,298	394	548	-127	19	32	1,405	232	497	6,008
1942	106	1,064	331	1,055	452	217	138	387	327	427	294	476	5,273
1943	504	136	427	134	140	209	196	12	549	462	584	1,292	4,645
1944	1,295	916	201	293	416	170	60	202	207	51	878	1,197	5,885
1945	977	801	446	554	252	-15	57	15	62	696	156	798	4,799
1946	1,093	820	583	531	495	-3	4	-68	564	616	653	454	5,741
1947	302	114	481	423	428	11	0	127	64	7	33	287	2,277
1948	68	1,117	544	286	225	138	113	82	88	87	399	370	3,517
1949	1,790	1,565	598	2,379	70	191	112	50	34	800	140	1,441	9,170
1950	703	1,264	195	934	336	143	129	67	363	109	56	35	4,334
1951	19	238	384	232	578	424	93	43	172	107	107	128	2,526
1952	104	147	536	948	88	45	32	175	356	0	413	674	3,517
1953	136	401	351	315	87	41	436	136	106	329	83	391	2,813
1954	212	11	0	21	125	91	21	63	8	170	106	60	888
1955	143	497	361	261	489	290	151	65	47	46	57	113	2,520
1956	219	474	181	84	72	31	15	18	28	8	93	115	1,337
1957	182	479	1,252	897	671	646	-29	-1	688	487	272	133	5,676
1958	486	573	1,340	643	-31	-13	19	0	766	858	415	230	5,286
1959	275	912	311	941	171	-65	54	53	109	1,507	460	591	5,320
1960	789	224	583	240	386	-752	499	143	2	1,084	659	430	4,286
1961	117	25	202	187	0	228	197	75	54	245	730	387	2,446
1962	317	511	761	534	-11	62	30	-5	424	439	513	790	4,364
1963	214	713	149	315	2	64	61	104	117	87	457	470	2,754
1964	1,159	1,186	666	175	82	151	27	80	280	434	660	312	5,213
1965	1,797	736	623	307	395	201	-19	1	147	955	559	1,091	6,793
1966	922	911	220	173	502	72	11	95	316	128	0	43	3,395
1967	0	38	166	86	107	31	26	45	578	474	741	568	2,860
1968	688	540	490	736	598	144	-69	0	194	111	903	1,241	5,575
1969	439	874	835	631	791	97	-1	53	148	739	767	244	5,619
1970	497	773	955	326	390	195	0	42	597	834	0	68	4,677
1971	0	194	7	38	189	99	34	851	499	1,115	891	855	4,771
1972	413	301	62	109	368	203	51	-9	90	307	934	285	3,115
1973	1,012	796	612	1,019	210	-209	-144	192	633	647	382	192	5,341
1974	793	42	499	179	1,056	30	19	384	265	599	1,395	585	5,845
1975	236	108	812	705	928	-204	405	-59	42	152	110	538	3,773
1976	295	236	630	2,061	685	104	820	-21	175	1,477	549	517	7,528
1977	1,036	729	722	942	220	112	0	0	0	78	582	96	4,517
1978	137	1,149	458	301	117	98	22	126	499	104	2,040	207	5,259
1979	1,152	208	1,182	740	172	24	-475	110	107	42	82	428	3,773
1980	466	858	432	87	794	-111	0	-13	907	227	830	483	4,961
1981	697	486	1,014	276	246	836	267	6	64	609	507	294	5,302
1982	416	363	254	264	1,110	105	15	53	45	79	683	965	4,351
1983	699	866	1,603	46	295	171	108	-100	241	356	599	294	5,179
1984	765	564	437	20	86	54	23	14	7	1,235	581	1,001	4,788
1985	719	681	720	701	247	-321	-87	0	371	778	1,823	49	5,679
1986	486	286	357	168	622	1,322	0	0	585	1,347	681	1,141	6,995
1987	497	909	530	273	-41	886	535	0	76	26	1,213	449	5,352
1988	343	478	417	263	294	292	102	38	11	69	12	94	2,413
1989	854	306	860	541	684	47	0	21	13	174	308	104	3,911
1990	388	1,245	2,201	1,058	629	31	348	49	62	450	844	167	7,474
1991	1,735	726	502	548	804	313	117	78	609	256	220	5,147	11,055
1992	303	155	738	1,025	436	116	-13	-21	0	0	577	820	4,137
1993	1,064	904	900	475	778	346	0	0	0	245	322	298	5,333
1994	475	887	1,250	433	737	192	0	0	347	1,753	298	1,200	7,573
1995	469	568	897	780	-37	233	21	0	349	68	469	360	4,176
1996	1	15	298	236	128	288	50	825	857	238	702	624	4,261
1997	480	1,246	1,093	1,022	1,049	279	-65	-24	70	568	743	1,382	7,842
1998	468	969	787	179	0	0	54	184	318	65	482	95	3,601
Average (1934-1998)	577	602	604	528	381	162	76	76	241	432	524	611	4,815
Drought Avg. (1952-1956)	163	306	286	326	172	100	131	91	109	111	150	270	2,215

average costs for different control methods and the cost share rates. The methods of brush control that the TSSWCB can approve are those which:

1. Are proven effective and efficient for brush control,
2. Are cost-effective,
3. Have beneficial impact on wildlife habitat,
4. Will maintain topsoil to prevent erosion or siltation, and
5. Will allow for revegetation of the area with plants that are beneficial to livestock and wildlife.[14]

Acceptable brush control methods vary depending upon the extent of control needed as well as the type of brush present. The U.S. Department of Agriculture, Natural Resources Conservation Service has a conservation practice standard for brush management.[15] The standard includes biological, chemical, mechanical, and burning methods for brush control. The biological method describes the use of goats for specific vegetation goats eat. The method involves defoliation of brush systematically. The standard does not include Ashe Juniper as a brush that would be controlled by the goats. Another standard is for the use of herbicides for brush control. A review of Texas Agricultural Extension Service on-line Expert System for Brush and Weed Control Technology Selection, Version 1.09 (Exsel)[16] for Uvalde County provided information on chemical agents for control of brush (Table 4C.28-16).

The mechanical standard prescribes plowing, grubbing, chaining, and dozing as primary brush control methods. In most cases Natural Resources Conservation Service recommends burning to control sprouts. For control of Ashe Juniper, the recommended method is using 50-pound per link chain one direction or two ways, particularly where juniper canopy exceeds 35 percent. Dozing can be used on juniper so long as the trees are uprooted below the bud zone, but dozing is not recommended due to the harmful effect on seed sources of preferred plants. For control of mesquite, post oak, and shin oak the preferred mechanical method is root-plowing or grubbing. Control of these types of brush requires uprooting the plants.

[14] Texas State Soil and Water Conservation Board, "Draft State Brush Control Plan," April 1, 1999
[15] Natural Resources Conservation Service, Conservation Practice Standard, Brush Management (Acre) Code 314.
[16] http://cnrit.tamu.edu/rsg/exsel/work/exsel.cgi

Table 4C.28-16.
Chemical Agents for Control of Brush

Brush	***Chemical Agent***	***Control Level[1]***
Ashe Juniper	Velpar L (hexazinone)	Very high control level
	Tordon 22K (picloram)	Very high control level
Blackjack Oak	Velpar L	Very high control level
	Spike 20P (tebuthiron)	Very high control level
	Crossbow	High control level
Live Oak	None recommended	
Mesquite	Remedy (triclopyr)	Very high control level
	Reclaim (clopyralid)	Very high control level
	Tordon 22K	Very high control level
	Velpar L	High control level
Post Oak	Velpar L	Very high control level
	Spike 20P	Very high control level
	Crossbow	High control level
Very high means 76 to 100 percent of plants killed; High means 56 to 75 percent killed.		

The State of Texas, through the TSSWCB, approaches the cost of brush management on a cost-sharing basis with the ranchers. The presumption in the state brush control program is to equate rancher costs with rancher benefits. The benefit to ranchers would be the increases in income from cattle, sheep, and wildlife businesses that result from brush control. For the livestock businesses, other things equal, increasing the amount of useable vegetation could increase the net economic return to the rancher because the grazing capacity of the rangeland would be expanded through controlling brush. Economic benefits received by ranchers who practice brush control will be attributed largely to the economy of scale realized through increased production without a corresponding increase in costs. Once the total cost of brush control is determined, then the difference between the total cost and the benefit to the rancher would be the cost that might be attributed to the additional water yield. Rangeland owners who do not depend on agricultural income may not have direct economic benefits from brush control. Presumably, if the rancher receives no benefits, then the rancher would not be interested in engaging in practices that increase costs. Brush control costs in this case would probably be borne by the State or the regional water authority that would benefit from the increased water supply resulting therefrom.

Studies have been done to determine brush control costs for rangelands in Texas.[17,18,19] Since these studies have occurred in the Edwards Plateau area which overlays part of the South Central Texas Region, the evaluation of this option is based on the assumption that the costs developed from these studies are relevant for use in evaluating this option. Table 4C.28-17 shows the treatment cost and present value for controlling nine different brush conditions of the Northern portion of the Nueces River Watershed downstream of the Edwards Aquifer recharge zone between USGS station at Uvalde (USGS #0819200) and Asherton (USGS #01893000). Present values of costs range from $170.42 per acre for rootplowing to control heavy mesquite or mixed brush, to $83.99 per acre for herbicide treatment of moderate mesquite. Costs are presented on a present worth basis because brush control requires an initial (year "0") investment plus a periodic future investment to maintain control.

4C.28.4 Environmental Issues

In general, brush management encompasses the control of junipers, mesquites and other woody species that compete with native grasses for water, light and nutrients, but whose growth may be encouraged by conventional land use practices. In the context of water supplies for Region L, brush management means reduction of juniper cover on Edwards Plateau watersheds upstream of the Edwards Aquifer recharge zone to increase runoff that might percolate to the Edwards Aquifer. Environmental concerns with brush control projects focus primarily on the reduction or removal of the wildlife habitat provided by the brush cover, and secondarily on the potential for soil erosion from exposed, disturbed soils where mechanical clearing methods are used, or the effects of herbicides on non-target species when chemical methods are employed.

Chaining, cabling, disking and other mechanical methods that strip brush displace resident wildlife populations, remove the habitat on which they depend and expose soil surfaces to erosion by wind and water. Brush management guidelines applicable to Edwards Plateau habitats are available from the Texas Parks and Wildlife Department and the Texas State Soil and Water Conservation Board that can be used to avoid or minimize potential impacts, but individual management plans should be developed for specific locations that take into account

[17] Walker, J.W., F. B. Dugas, F. Baird, S. Bednarz, R. Muttiah, and R. Hicks, "Site Selection for Publicly Funded Brush Control to Enhance Water Yield," Proceedings, Water for Texas Conference, Austin, Texas, December 1998.
[18] Bach, Joel P. and J. Richard Connor, "Economic Analysis of Brush Control Practices for Increased Water Yield: The North Concho River Example," Proceedings, Water for Texas Conference, Austin, Texas, December 1998.
[19] HDR, "Brush Control Planning, Assessment, and Feasibility Study, December 2000.

Table 4C.28-17.
Initial and Interim Costs for Various Brush Control Methods (Northern Portion of Nueces River Watershed)

Year	***Treatment***	***Treatment Cost ($/acre)***	***Present Value ($/acre)***
Heavy Mesquite — Chemical Herbicide[1]			
0	Chemical Herbicide	45.00	45.00
4	Chemical Herbicide	40.00	29.40
7	Choice IPT or Burn	25.00	14.59
		Total	88.99
Heavy Mesquite — Rootplow[2]			
0	Rootplow	110.00	110.00
5	Choice IPT or Burn	30.00	20.42
		Total	130.42
Extra Heavy Mesquite — Rootplow with Pre-Doze[3]			
0	Pre-doze and Rootplow	150.00	150.00
5	Choice IPT or Burn	30.00	20.42
		Total	170.42
Heavy Mixed Brush — Chemical Herbicide[4]			
0	Chemical Herbicide	90.00	90.00
5	Choice IPT or Burn	35.00	23.82
		Total	113.82
Heavy Mixed Brush — Chop Method[5]			
0	Choice of Chop Method	45.00	45.00
4	Choice Chop, IPT, or Burn	45.00	33.08
7	Choice IPT or Burn	25.00	14.59
		Total	96.67
Heavy Mixed Brush — Rootplow[2]			
0	Rootplow	100.00	100.00
5	IPT or Burn	30.00	20.42
		Total	120.42
Extra Heavy Mixed Brush — Rootplow with Pre-Doze[3]			
0	Pre-Doze and Rootplow	150.00	150.00
5	IPT or Burn	30.00	20.42
		Total	170.42

Table 4C.28-17.
Initial and Interim Costs for Various Brush Control Methods (Northern Portion of Nueces River Watershed)(continued)

Year	***Treatment***	***Treatment Cost ($/acre)***	***Present Value ($/acre)***
Moderate Mesquite — Chemical Herbicide[1]			
0	Aerial or IPT Herbicide	40.00	40.00
4	Aerial or IPT Herbicide	40.00	29.40
7	Choice IPT or Burn	25.00	14.59
		Total	83.99
Moderate Mixed Brush — Chemical Herbicide[1]			
0	Aerial or IPT Herbicide	40.00	40.00
4	Aerial or IPT Herbicide	40.00	29.40
7	Choice IPT or Burn	25.00	14.59
		Total	83.99

[1]Either aerial or individual chemical application may be used.
[2]Rootplow, rake, stack, and burn.
[3]Heavy tree-doze, rootplow, rake, stack, and burn. Note: canopy cover for this practice is 40% or greater.
[4]Choice of roller-chop, aerator method, or deep disking.

Source: HDR, "Brush Control Planning, Assessment, and Feasibility Study," December 2000.

Table 4C.28-18.
Present Worth and Uniform Annual Costs for
30-Year Brush Control Projects under Varying Brush Conditions

Brush Condition	***Present Worth Per Acre (2nd Quarter 2002 Costs)***	***Uniform Annual Cost (per acre)[1]***
Heavy mesquite	$182.77	$13.28
Moderate mesquite	$174.30	$12.66
Moderate mixed brush	$174.30	$12.66

[1] Amortized over 30 years at 6 percent interest.

the topography of the site, the character of the brushy cover and the vegetation intended to replace it, local and regional wildlife needs, and the potential for impacts to endangered species. Management practices may include limitation of clearings to slopes of less than 10%, avoiding disturbance to riparian areas, limiting the size of cleared areas and limiting the proportion of open to wooded habitat to about 2:1. Low impact hand techniques that clear brush in a patchwork fashion, leaving brush berms to control erosion and provide protection for wildlife, may be necessary where soils on slopes are thin and droughty.

Chemical methods of brush control carry some risk of chemical runoff into streams and subsequent percolation into the underlying aquifers. The chemicals to be used should be applied strictly according to the label directions to avoid toxicity to aquatic organisms. Where large areas are to receive herbicide treatments, stream monitoring (particularly storm flows) above the recharge zone for those substances may be necessary to evaluate potential exposures to water users and endangered species resident in the aquifer and its large spring openings.

4C.28.5 Engineering and Cost of Brush Control

A general cost estimate of enhanced water yield from brush control for counties in South Central Texas can be reasonably estimated because of the history of brush control practices in Texas (Table 4C.28-6). The costs in Table 4C.28-18 were computed using 30 years as the project horizon, adjusted to reflect Second Quarter 2002 prices, 6 percent interest, and the initial and periodic (recurring costs to maintain the practice in a productive condition) costs in Table 4C.28-17 for brush control for chemical treatment followed by prescribed burn.

Cost for each condition is the uniform annual cost of the present worth of the initial costs and the periodic control costs. For the Nueces and Blanco Basins, it was assumed that moderate mixed brush would be appropriate brush condition for costing purposes.

For the Nueces Basin, brush management of 35 percent of the acreages having Ashe Junipers (i.e., evergreen forest) would require treatment of 284,000 of the 1,200,000 acres in the Nueces Recharge Basin (Figure 4C.28-1). At a uniform annual cost of $12.66 per acre, the total annual cost of a brush management program in the Nueces Basin is $3,594,000. For an increased sustained yield of 1,728 acft/yr from the Edwards Aquifer (Section 4C.28.2), the unit cost is estimated at $2,080 per acft. This cost is based on increases in sustained yield from the Edwards Aquifer and effects of brush management projects would be different for other aquifer systems.

For the Blanco Basin, brush management of 35 percent of the acreages of Ashe Junipers (i.e. evergreen forest) would require treatment of 83,000 acres of the 340,000 acres in the Blanco Recharge Basin (Figure 4C.28-2). At a uniform annual cost of $12.66 per acre, the total annual cost of a brush management program in the Blanco Basin is $1,054,000. For an increased sustained yield of 540 acft/yr from the Edwards Aquifer (Section 4C.28.2), the unit cost is estimated at $1,952 per acft. This cost is based on increases in sustained yield from the Edwards Aquifer and is not necessarily applicable to other basins.

4C.28.6 Implementation Issues

Several implementation issues pertain to this potential water supply option. *In situ* brush control studies have been effective for catchment-level examples of areas of 1,000 acres or less. To make a significant impact upon increasing the yield of recharge to the Edwards, Trinity, and Carrizo Aquifers, brush control would have to be practiced over a considerable area. The Nueces and Blanco Recharge Basins (Figures 4C.28-1 and 4C.28-2), covering 1,200,000 and 340,000 acres, respectively, are significantly larger than typical brush control study areas and will require significant participation from stakeholders and state and federal agencies to achieve program goals for additional water supply. It is not proven that a large-scale brush control program would be practical because it would require the cooperation of many different landowners having different interests in their property. In a specific target watershed, there may be property owners who are not dependent on grazing income and therefore have limited interest in brush control. To ensure cooperation of these ranch owners, additional subsidies or other considerations may be required which could alter the cost profiles for brush control.

Another issue is that most of the assumptions and results presented above are based on computer modeling rather than *in situ* examples that have the benefit of several years of performance to demonstrate results. It would be recommended that much more research be performed *in situ* at specific sites before public funds are invested in major projects.

One critical implementation issue is how the increase in runoff and/or recharge resulting from brush control would be related to water supply yield for other aquifer systems. Key questions that need answers are:

- How is the increased runoff and/or recharge verified?
- How much of the increased runoff and/or recharge results in yields of affected aquifers? and
- How is the increased yield of the affected aquifers verified?

Evaluations of this regional water management strategy for the Nueces and Blanco Basins are provided in Tables 4C.28-19 and 4C.28-20.

Table 4C.28-19.
Evaluations of Brush Management to
Enhance Water Supply Yield- Nueces Recharge Basin

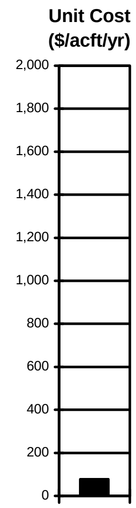
Impact Category	***Comment(s)***
a. Water Supply	
1. Quantity	1. Sustained Yield Increase from Edwards Aquifer: 1,728 acft/yr
2. Reliability	2. Good reliability
3. Cost of Treated Water	3. High cost: $2,080 per acft
b. Environmental factors	
1. Instream flows	1. May increase runoff and instream flows
2. Bay and Estuary Inflows	2. May increase bay and estuary inflows, depending on location of brush management.
3. Wildlife Habitat	3. Brush control techniques may adversely affect existing wildlife populations
4. Wetlands	4. None or low impact.
5. Threatened and Endangered Species	5. May have negative affect on habitats for endangered species.
6. Cultural Resources	6. None or low impact.
7. Water Quality	7. Chemical brush control methods may result in residual chemicals in aquifers & streams.
c. Impacts to State water resources	No apparent negative impacts on other water resources Benefit to Edwards Aquifer water resources due to increased water for recharge.
d. Threats to agriculture and natural resources in region	Potential threats to habitat due to removal of brush
e. Recreational impacts	Could impact hunting
f. Equitable comparison of strategies	Costs for brush control is relatively high
g. Interbasin transfers	Not applicable
h. Third party social and economic impacts from voluntary redistribution of water	Not applicable
i. Efficient use of existing water supplies and regional opportunities	Improvement over current conditions
j. Effect on navigation	None

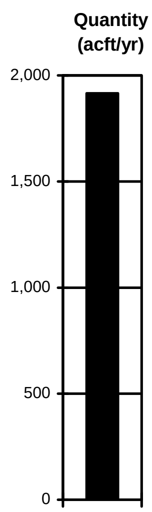
Table 4C.28-20.
Evaluations of Brush Management to
Enhance Water Supply Yield- Blanco Recharge Basin

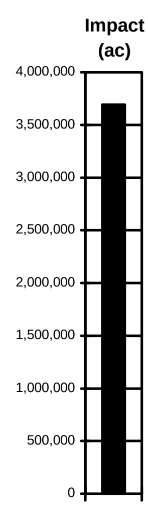
Impact Category	***Comment(s)***
a. Water Supply	
1. Quantity	1. Sustained Yield Increase from Edwards Aquifer: 540 acft/yr
2. Reliability	2. Good reliability
3. Cost of Treated Water	3. High cost: $1,952 per acft
b. Environmental factors	
1. Instream flows	1. May increase runoff and instream flows
2. Bay and Estuary Inflows	2. May increase bay and estuary inflows, depending on location of brush management.
3. Wildlife Habitat	3. Brush control techniques may adversely affect existing wildlife populations
4. Wetlands	4. None or low impact.
5. Threatened and Endangered Species	5. May have negative affect on habitats for endangered species.
6. Cultural Resources	6. None or low impact.
7. Water Quality	7. Chemical brush control methods may result in residual chemicals in aquifers & streams.
c. Impacts to State water resources	No apparent negative impacts on other water resources Benefit to Edwards Aquifer water resources due to increased water for recharge.
d. Threats to agriculture and natural resources in region	Potential threats to habitat due to removal of brush
e. Recreational impacts	Could impact hunting
f. Equitable comparison of strategies	Costs for brush control is relatively high
g. Interbasin transfers	Not applicable
h. Third party social and economic impacts from voluntary redistribution of water	Not applicable
i. Efficient use of existing water supplies and regional opportunities	Improvement over current conditions
j. Effect on navigation	None

(This page intentionally left blank.)

2006 South Central Texas Regional Water Plan
Water Management Strategy Summary Sheet







Name:* *Weather Modification - Nueces Recharge Basin

Description: Enhancing rainfall through seeding of clouds within the planning area with silver iodide in order to increase water supplies for direct use and for Edwards Aquifer recharge in Nueces Basin Recharge areas.

***Decade Needed*: 2010 – 2060**

Cost, Quantity of Water, and Land Impacted

Unit Cost of Water:	**77**	**$/acft/yr**	**Increase in Sustained Yield from Edwards Aquifer**
Quantity of Water:	**1,916**	**acft/yr**	**Reliability = Firm**
Land Impacted:	**3,693,440**	**acres**	

Additional Considerations per Regional Water Planning Guidelines

Environmental Factors: May increase runoff and instream flows.

Impacts on Water Resources: Benefit to Edwards Aquifer water resources due to increased water for recharge. No apparent negative impacts on other water resources.

Impacts on Agricultural & Natural Resources: Potential benefit to farmers and ranchers through increased rainfall. Potential threats due to limited risk of increased flooding.

Other Relevant Factors per SCTRWPG: Additional water supply and costs are only applicable to increased sustained yield of the Edwards Aquifer and the Nueces and Blanco Recharge Basins. Costs and additional water supply would be different for other aquifer systems and watersheds. Weather modification costs were based on current costs of existing weather modification programs in South Central Texas Region.

Comparison of Strategies to Meet Needs: Low unit cost, and no conflicts with other recommended water management strategies.

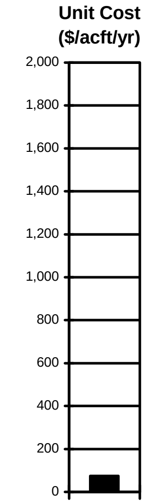
Interbasin Transfer Issues: Not applicable.

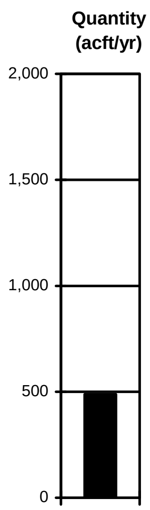
Third-Party Impacts of Voluntary Transfers: Not applicable

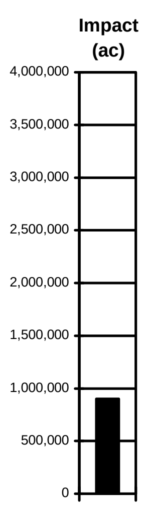
Regional Efficiency: Good, provided continuous funding.

Water Quality Considerations: None or low impact.

2006 South Central Texas Regional Water Plan
Water Management Strategy Summary Sheet







Name:* *Weather Modification - Blanco Recharge Basin

Description: Enhancing rainfall through seeding of clouds within the planning area with silver iodide in order to increase water supplies for direct use and for Edwards Aquifer recharge in Blanco Basin Recharge areas.

***Decade Needed*:** **2010 – 2060**

Cost, Quantity of Water, and Land Impacted

Unit Cost of Water:	**74**	**$/acft/yr**	**Increase in Sustained Yield from Edwards Aquifer**
Quantity of Water:	**488**	**acft/yr**	**Reliability = Firm**
Land Impacted:	**901,120**	**acres**	

Additional Considerations per Regional Water Planning Guidelines

Environmental Factors: May increase runoff and instream flows.

Impacts on Water Resources: Benefit to Edwards Aquifer water resources due to increased water for recharge. No apparent negative impacts on other water resources.

Impacts on Agricultural & Natural Resources: Potential benefit to farmers and ranchers through increased rainfall. Potential threats due to limited risk of increased flooding.

Other Relevant Factors per SCTRWPG: Additional water supply and costs are only applicable to increased sustained yield of the Edwards Aquifer and the Nueces and Blanco Recharge Basins. Costs and additional water supply would be different for other aquifer systems and watersheds. Weather modification costs were based on current costs of existing weather modification programs in South Central Texas Region.

Comparison of Strategies to Meet Needs: Low unit cost, and no conflicts with other recommended water management strategies.

Interbasin Transfer Issues: Not applicable.

Third-Party Impacts of Voluntary Transfers: Not applicable

Regional Efficiency: Good, provided continuous funding.

Water Quality Considerations: None or low impact.

4C.29 Weather Modification

4C.29.1 Weather Modification and Methods

Weather modification as it has been applied in Texas over the past 25 to 30 years involves cloud seeding to increase rain above what would have naturally occurred. The result of cloud seeding is referred to as rainfall enhancement. The concept of how this occurs is described below.

In natural rainfall, droplets are created from the presence of ice particles (crystals) in the cloud. These crystals are formed when freezing water contacts particles of dust, salt or sand. The ice crystals form a nucleus around which water droplets attach to make the size of the droplet increase. When the size of a droplet increases sufficiently, it becomes a raindrop and falls from the cloud. Cloud seeding is thought to increase the number of these "nuclei" available to take advantage of the moisture in the cloud to form raindrops that would not have otherwise formed. To be effective, seeding must be done at the correct time and in the correct manner.

As a cloud grows taller, the air temperature in the cloud cools and falls below the freezing point of water. This cooling effect means that the cloud droplets, which are much too small to fall as rain, are also cooled to a point where they respond to crystallization when contacted by an ice particle. Consequently, when there are fewer crystals to act as nuclei for raindrops, there will be less rain than would have been if more crystals were present. Although crude experiments to enhance rainfall were attempted in the U.S. as early as the mid-1800s, modern weather modification was begun in 1946 through an unintended laboratory event.

In 1946, V. Schaefer was involved with the General Electric Laboratory doing research to create artificial clouds in a chilled chamber. During one experiment, Schaefer believed the chamber was too warm, and, to cool it, he placed dry ice in the chamber. With the chilled water vapor in the chamber, ice crystals formed a cloud around the dry ice. Believing dry ice would not be practical to transport to emerging rain clouds, Schaefer's colleague, Bernard Vonnegut, searched for a chemical that almost exactly matched the chemical structure of ice crystals. It was found that silver iodide was such a chemical.[1] Silver iodide is termed "glaciogenic" because its chemical structure is like ice crystals. The other seeding chemical used when the cloud temperature is too warm for forming ice is calcium chloride (CaCl). Calcium chloride is "hygroscopic," which means it attracts water.

[1] Jensen, Ric, "Does Weather Modification Really Work?", Texas Water Resources, Summer 1994.

When silver iodide is introduced into a cloud, the number of ice crystals increases and the crystals attach to water vapor causing it to freeze to the crystal. Considerable heat is released to the atmosphere during the freezing and crystal formation phase. The released heat causes the cloud to grow taller and its vertical wind velocity (updraft) to increase. This results in the cloud being able to pull in more moist air and, thus, create more raindrops. However, not all clouds are potential rainmakers. Generally, cloud seeding is performed with a meteorologist working in tandem with the pilot of the cloud seeding aircraft so that, with direction from the meteorologist, the pilot can target the most promising cloud(s).[2] The criteria used in Texas to find promising clouds, is to locate "feeder" cells near developing cloud formations which have temperatures below 23^{o} F. The target cloud must also have sufficient moisture and airflow to be a candidate. Based on a cloud seeding program conducted by the Edwards Aquifer Authority from 1999 to 2001, seeded events typically occurred during spring and summer months (April- September) and were performed on days with anticipated precipitation up to 3 inches based on radar.[3,4] About 20 or 30 minutes prior to the desired rainfall event, the candidate cloud is seeded when the airplane releases silver iodide particles in a plume, typically at the base of the cloud so the updraft can draw the particles upward and make more contact with water in the cloud. Seeding has another effect on large, potentially dangerous thunderstorms capable of causing hail. Seeding tends to mitigate the extreme freezing that results in forming large particles of ice (hail) and makes the moisture more likely to fall as rain.

The criteria for cloud seeding based on experience in Texas since the early 1970s are the following:

- The cloud must be "convective" meaning that it displays instability in the atmosphere.
- Temperature at the top of the cloud must be 23^{o} F or less.
- The base of the cloud must be less than 12,000 feet elevation.

Clouds having the characteristics listed above exhibit a warm base, a strong updraft, and sufficient heat to carry water vapor to the cloud top.

[2] Clouds may also be seeded using ground-based silver iodide dispensers. However, in this discussion, only the aircraft method is considered.
[3] Edwards Aquifer Authority, "Rainfall Data Summary and Assimilation", December 2002.
[4] Cloud seeding occurred in the Blanco Basin when daily precipitation was less than 3 inches and in the Nueces Basin when less than 2.5 inches.

A summary of recent cloud seeding experiments in Texas, Florida, Cuba, and Southeast Asia has been presented by the TCEQ in a public information document entitled, "Some Facts about Cloud Seeding from Recent Research on Rain Enhancement in Texas".[5] The TCEQ concludes the following:

- Cloud seeding with AgI increases rain generated by these clouds by extending the life of the clouds, by allowing the clouds to enlarge laterally so that they cover more area, and by slightly increasing the height of the clouds.
- Rain production of seeded clouds is more efficient than for non-seeded clouds.
- The timing of seeding and the selection of clouds are fundamental. These are such critical factors that "…seeding at the wrong time and in the wrong place(s) may actually decrease the rainfall."[6]

In 2004, the American Society of Civil Engineers (ASCE) published a standard practice for cloud seeding technology applications for precipitation enhancement projects.[7] The standard includes procedures such as personnel, decision-making, communications, safety issues, and seeding suspension criteria.

4C.29.2 Precipitation Enhancements from Weather Modification Programs in Texas

The findings from several Texas cloud seeding programs are summarized below. This will provide a basis for determining the reasonableness of assumptions for the potential quantities resulting from weather modification in the South Central Texas Region. The programs to be discussed are the Southwest Cooperative Program (SWCP), the Texas Experiment in Augmenting Rainfall through Cloud-Seeding (TEXARC), the Colorado River Municipal Water District (CRMWD) Program, the Edwards Aquifer Authority (EEA) Program, the South Texas Weather Modification Association (STWMA) Program, and the Southwest Texas Rain-Enhancement Association (SWTREA) Program. Each of these programs is described below

Southwest Cooperative Program (SWCP): The program was begun in 1986 as a cooperative effort between Oklahoma and Texas "…to develop a scientifically sound, environmentally sensitive, and socially acceptable, applied weather modification technology for increasing water supplies…in the southern High Plains."[8] The area involved was 5,000 square

[5] Bomar, George, "Some Facts about Cloud Seeding from Recent Research on Rain Enhancement in Texas," Texas Commission on Environmental Quality, 1999.
[6] George Bomar, TCEQ Senior Meteorologist, Austin, Texas.
[7] American Society of Civil Engineers, "Standard Practice for the Design and Operation of Precipitation Enhancement Project", 2004.
[8] Bomar, George, William L. Woodley, and Dale L. Bates, "The Texas Weather Modification Program: Objectives, Approach, and Progress," Journal of Weather Modification, April 1999.

miles located between Midland-Odessa and Lubbock. Random cloud seeding experiments were conducted in 1986, 1987, 1989, 1990, and 1994.

During the period 1987 through 1990, 183 experiments were made (93 seeded, 90 non-seeded). The criteria for selection were the following:

- Liquid water content had to be at least 0.5 gm/m^3 and updrafts had to be at least 1,000 ft/min.
- The target had to be a multiple-cell convective unit.
- No cloud or cell height could exceed 10 km (above ground level).
- Some of the tops had to have temperatures -10^o C or colder.

The results confirmed increased rainfall. Compared to the non-seeded cells, the seeded cells displayed an increase in maximum height of 7 percent, an increase in the coverage of the rainfall event of 43 percent, an increase in the storm duration of 36 percent, and an increase in rain volumes.[9]

Texas Experiment in Augmenting Rainfall through Cloud Seeding (TEXARC): The State of Texas implemented the program in 1994 and 1995 to investigate physical processes within large storms in the San Angelo area. This research was focused on understanding the best ways of seeding clouds to make them more efficient producers of water, rather than quantifying the results. The results showed that seeding must be within the super-cooled updraft region of the cloud in order to increase rainfall. From this research it was shown that the seeding agent must be carefully placed either directly in the top of the updraft, or at the entrance to the updraft at the base of the cloud.

Colorado River Municipal Water District (CRMWD) Program: Having been started in 1971, this is the longest-running operational weather modification program in Texas. The target area is roughly the upper Colorado River Basin upstream from Spence Reservoir, comprising some 3,600 square miles. The goals for the program have always been first, to increase water supplies to Lake Thomas and Spence Reservoir, and secondly, to increase rainfall to agricultural areas. The reported long-term results are that there was a 34 percent increase (above normal historic precipitation) in the seeded areas and a 13 percent increase in non-seeded areas.[10,11]

[9] Rosenfeld, D. and W. L. Woodley, “Effects of Cloud Seeding in West Texas: Additional Results and New Insights,” Journal of Applied Meteorology, 1993.
[10] Jones, R., “A Summary of the 1988 Rainfall Enhancement Program and a Review of the Area Rainfall and Primary Crop Yield,” Report 88-1 of the Colorado River Municipal Water District, 75 pages, 1988.
[11] Jones, R., “A Summary of the 1997 Rainfall Enhancement Program and a Review of the Area Rainfall and Primary Crop Yield,” Report 97-1 of the Colorado River Municipal Water District, 54 pages, 1997.

Edwards Aquifer Authority (EAA) Program: (*substantial portions of this program description were reproduced from the EEA web page, e-aquifer.com, and are presented here unedited*)

"The Edwards Aquifer Authority board of directors voted in the fall of 1997 to obtain a permit to conduct precipitation enhancement, or cloud seeding, from the Texas Natural Resources Conservation Commission (now TCEQ). The Authority contracted with Weather Modification, Inc., to complete and submit the permit application on the Authority's behalf, and work with the TCEQ. The permit was granted by TCEQ in October 1998 and was valid for 4 years from January 1999 through December 2002. The permit allowed the Authority to conduct precipitation enhancement anytime during the year, including the traditional period of April through September. The Authority committed $500,000 for the 1999 program with half the expenses reimbursed by the TCEQ."

"Each county in the target and South Central Texas Water Advisory Committee (SCTWAC) areas of the program can appoint a representative to sit on a Precipitation Enhancement Advisory Group. The group will work with the Authority in alerting the contractor about local conditions. The ways this committee has worked included communicating saturation conditions so that flights are suspended to avoid flood conditions and during periods when crops are being harvested. The assumption for enhanced aquifer recharge was 10 percent above the recharge quantity, which would occur without enhancement."

From 1999 through 2001, the Edwards Aquifer Authority contracted Weather Modification Inc. to perform weather modification services for the EAA Precipitation Enhancement Program over the 12 target counties presented in Table 4C.29-1. Woodley Weather Consultants[12] evaluated the data collected, which included 39 seeding events for the Blanco Basin and 21 seeding events for the Nueces Basin. This study area included six of the 12 target counties, including Kendall, Blanco, Hays, Comal, Real, and Uvalde Counties. In 2003, a study[13] was conducted to determine enhanced recharge attributable to the 1999 to 2001 seeding events, which concluded that the total increased recharge during the 3-year period was 1,972 acft in the Nueces Basin (a 0.29 percent increase) and 1,332 acft in the Blanco Basin (1.13 percent increase).[14]

---

[12] Edwards Aquifer Authority, "Rainfall Data Summary and Assimilation," December 2002.
[13] LBG-Guyton Associates, "Assessment of Recharge Benefit from Enhanced Rainfall," June 2003.
[14] Note: Only half of the Nueces Basin was in the cloud seeding zone, which may have reduced the impact of cloud seeding on recharge in that basin.

Table 4C.29-1.
Edwards Aquifer Authority Weather Modification Program Counties

Target Counties	*Operational Counties*	*SCTWAC Counties*[1]
Bandera, Bexar, Blanco, Caldwell, Comal, Guadalupe, Hays, Kendall, Kerr, Medina, Real (east of U.S. Highway 83), and Uvalde	Gillespie, portions of Atascosa, Burnet, Frio, Kimble, Llano, Real, Wilson, and Zavala	Calhoun, DeWitt, Goliad, Gonzales, Karnes, Nueces, Refugio, San Patricio, Victoria, Atascosa, Wilson, Uvalde, Medina, Bexar, Comal, Hays, Guadalupe, and Caldwell
[1]Coastal Bend Water Advisory Committee (SCTWAC), as created by Senate Bill 1477.		

In 2002, the Authority's Precipitation Enhancement Program was reduced to target Bandera, Bexar, Medina, and Uvalde Counties. South Texas Weather Modification Association was contracted by the Authority to seed Bexar, Bandera, and Medina Counties. Southwest Texas Rain Enhancement Association was contracted to seed Uvalde County. The current weather modification programs in South Central Texas and counties where they operate are presented in Figure 4C.29-1.

South Texas Weather Modification Association (STWMA) Program: This program was started in 1997 when the Evergreen Water District hired a contractor to conduct cloud seeding. In 1998, the addition of two pilots, a meteorologist, and the purchase of two planes enhanced this program considerably. The counties involved in the cloud seeding include Atascosa, Bee, Frio, Karnes, Live Oak, McMullen, and Wilson. Since 2002, Bexar, Bandera, and Medina Counties have been added to the program. According to the 2004 STWMA Annual Evaluation Report, an increase of 1,225,900 acft (2.23 inches) was reported across the ten-county program area attributable to 45 seeding events between April 2, 2004, and October 27, 2004. This translates to a precipitation increase of 10.4 percent, on average, with the weather modification program. The average increase in precipitation over the Edwards aquifer (Bandera, Medina, and Bexar Counties) was calculated at 7.3%. The thirteen counties in Region L included in the program are presented in Table 4C.29-2 along with reported precipitation increases. Uvalde County precipitation increases were reported by SWTREA. The highest precipitation increase was recorded for Atascosa County, at 14.8 percent.

Southwest Texas Rainfall Enhancement Association (SWTREA) Program: This program was begun in 1999 and is currently operated by the Wintergarden Groundwater Conservation District in Carrizo Springs, Texas. This program was the first of the nine existing weather

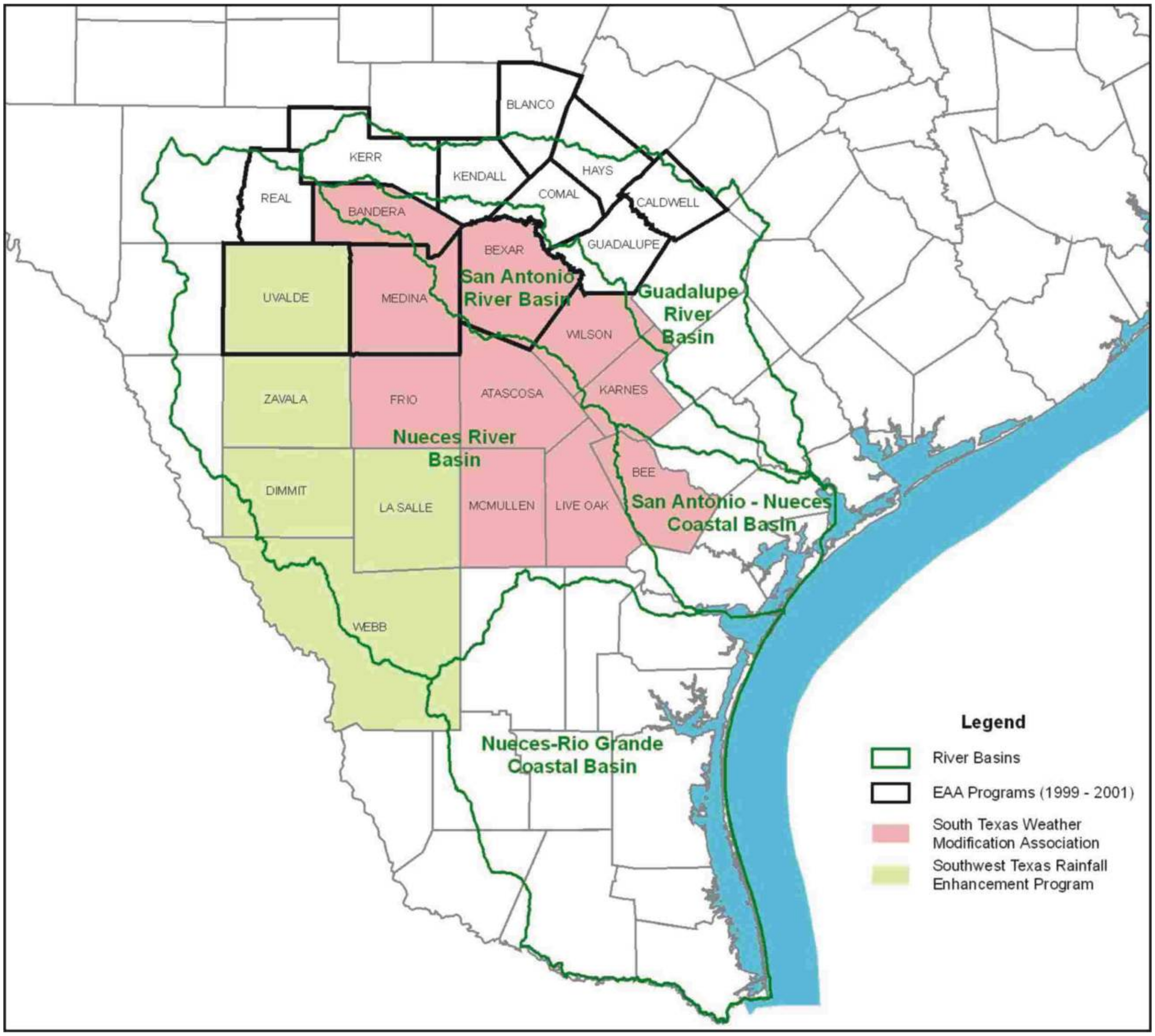


Figure 4C.29-1. South Central Texas Weather Modification Programs

modification programs in Texas to evaluate the suppression of hail. The original program consisted of Dimmit, LaSalle, and Webb Counties but was expanded in 2002 to include Uvalde County. According to the 2003 SWTREA Annual Evaluation Report, an increase of 36,773 acft (0.78 inches)[15] was reported over Uvalde County associated with 18 seeding events between May 26, 2003, and October 6, 2003. This translates to a precipitation increase of 5 percent for Uvalde County with the SWTREA weather modification program. The SWTREA four-county program area lies within the Nueces River Basin and South Central Texas Planning Area.

[15] Precipitation increase (in inches) was calculated by dividing acft increase by area of seeded sample (acres).

Table 4C.29-2.
Weather Modification Precipitation Enhancements in Region L Counties

Region L Counties	***Increases in Precipitation***		
	(acft)	***(inches)***	***(% increase)***
Atascosa	221,600	3.37	14.8
Bexar	79,300	1.19	5.0
Dimmit	4,800	0.07	NR
Frio	157,700	2.61	12.3
Goliad	5,900	0.13	NR
Gonzales	3,500	0.06	NR
Guadalupe	22,800	0.60	NR
Karnes	115,700	2.89	13.0
La Salle	59,000	0.74	NR
Medina	114,000	1.61	7.2
Uvalde*	36,773	0.73	5
Wilson	75,700	1.76	8.1
Zavala	25,500	0.32	NR

Source: STWMA Annual Evaluation Report 2004, except for Uvalde County from SWTREA Annual Report 2003.

NR= Not Reported

<u>Rainfall Enhancement Programs Underway in Texas during spring 2004</u>: There were nine cloud seeding programs in Texas that were funded, at least partially, by State funds from the Texas Department of Agriculture. The funds were apportioned in amounts up to $0.045 per acre to help counties pay for weather modification programs. The State contributed $1.82 million to sponsoring programs during the spring and summer of 2003. No new funds were appropriated by the 2003 (78th) Legislative Session and State funds were exhausted by spring 2004. However, these programs were continued through the seeding season of 2004 despite a lack of State support. The programs, the counties they cover and the approximate areas of coverage are presented in the Table 4C.29-3.

There have been several studies performed to quantify the increase of recharge attributable to weather modification. A USGS study on Upper Seco Creek Basin used an HSPF

Table 4C.29-3.
Cloud Seeding Programs Underway in Texas during Spring 2004

Cloud Seeding Program	Counties Involved	Area (sq. miles)
Colorado River Municipal Water District	Borden, Mitchell, and parts of Dawson, Howard, Sterling, Nolan, and Scurry	3,500
West Texas Weather Modification Association	Glasscock, Reagan, Crockett, Sutton, Schleicher, Irion and part of Tom Green	9,688
South Texas Weather Modification Association	Frio, Atascosa, McMullen, Live Oak, Bee, Karnes, Wilson, Bexar, Medina, Bandera	10,318
Southern Ogallala Aquifer Rain Program	Gaines, Terry, and Yoakum (Texas); and 2 million acres in eastern New Mexico near Gaines and Yoakum Counties	3,192 (in Texas)
North Plains Groundwater Conservation District	Dallam, Sherman, Hansford, Ochiltree, Lipscomb, and parts of Hartley, Moore, and Hutchinson	6,563
Panhandle Groundwater Conservation District	Carson, Donley, Gray, Roberts, and Wheeler	6,309
West Central Texas Weather Modification Association	Nolan, Taylor, Callahan, Eastland, Coke, Runnels, Coleman, Brown, and Comanche	7,656
Trans Pecos Weather Modification Association	Culberson, Loving, Reeves, and Ward	7,958
Southwest Rain Enhancement Association	Uvalde, Dimmit, La Salle, Zavala, and Webb	9,141

model to simulate weather modification and assumed a rainfall increase of 10% for Seco Creek subbasins for the entire 1991-1998 simulation period (USGS, 2002). The Edwards Aquifer Authority sites in their 2003 Edwards Aquifer Authority Hydrogeologic Data Report that “weather modification can increase precipitation by as much as 21%.”

An Edwards Aquifer Recharge study conducted by Guyton in 2003, which used results from the 1999-2001 EAA Precipitation Enhancement Program, assumed an average 10% total rainfall attributed to cloud seeding. The 1999-2001 Precipitation Enhancement Program data points deemed reliable (5 (out of 21 days) in the Nueces Basin and 8 (out of 39 days) in the Blanco Basin) were then used to assess the recharge benefits from enhanced rainfall for seeded events from 1999-2001. The study showed that if enhanced precipitation was assumed as one inch on each day for which cloud seeding was considered successful then a total increased recharge of 1% for the Nueces Basin and 4.2% for the Blanco Basin would be expected during the 3-year period (LBG Guyton, 2003). According to WWC data for the 13 days when cloud seeding was considered successful, 9 days the total enhanced precipitation was less than one inch (69% of the time).

The STWMA estimates 20-25% increase in rainfall due to cloud seeding, when compared to radar data rainfall predictions. Seeding typically occurs from April through September and seeding opportunities are limited to specific clouds as described earlier (correspondence Todd Flanagen, STWMA, 2004).

For the 2006 Plan, the South Central Texas Region Water Planning Group (SCTRWPG) requested a more detailed analysis of a long-term weather modification program. This effort included application of Pilot Recharge Models of the Nueces and Blanco River Basins (HDR, 2002) to quantify increases in streamflow and recharge enhancement to the Edwards Aquifer associated with weather modification. This recharge enhancement information was then processed by an Edwards Aquifer model (GWSIM4) to quantify potential increases in sustained yield. GWSIM4 Edwards Aquifer groundwater flow model developed by the Texas Water Development Board simulates Edwards aquifer response in terms of water levels and springflows for specified recharge and pumping rates.

4C.29.3 Using Hydrologic Simulation Program Fortran to Simulate Weather Modification

4C.29.3.1 Introduction

HDR conducted a study in June 2002 on behalf of the Edwards Aquifer Authority to develop Pilot Recharge Models of the Nueces and Blanco River Basins (HDR, 2002) to provide accurate daily recharge data to the Edwards Aquifer with sufficient accuracy to model enhanced recharge associated with new recharge dams, precipitation enhancement (weather modification), and brush management initiatives. The Pilot Recharge Models for the Nueces and Blanco River Basins used the Hydrologic Simulation Program-Fortran (HSPF) Release 11 to calculate daily recharge to the Edwards Aquifer. The pilot recharge models of the Nueces and Blanco Recharge Basins use hydraulic and hydrologic routines within HSPF to translate daily streamflow, rainfall, and evaporation into recharge and downstream flow by simulation of interception, overland flow, infiltration, evapotranspiration, shallow storage, deep percolation, and other hydrologic processes.[16]

[16] Edwards Aquifer Authority, Pilot Recharge Models of the Nueces and Blanco River Basins, June 2002.

The 2002 Pilot Recharge Models included for the Nueces Recharge Basin, eight land segments subdivided on the basis of geologic characteristics and observed streamflow loss rates and seven river reaches defined in accordance with an intensive streamflow loss survey conducted by the USGS (HDR, 2002). The land segments of the Nueces Basin extend over contributing (2), recharge (3), confined zones (2), and Leona Gravels (1) as well as associated reaches. The Blanco Recharge Basin included seven land segments and six river reaches (with additional reaches representative of seven existing flood retardation structures that serve to enhance Edwards Aquifer recharge) created according to the same method used for the Nueces Basin. The land segments of the Blanco Basin extend over contributing zone (1), recharge zones (4), confined zones (2), and Leona Gravels (1) as well as associated reaches. While the model works very well for estimating recharge based on historical conditions, since it was calibrated with a USGS gage on the upstream side of the recharge zone for both Nueces and Blanco Basins, it did not simulate the hydrology of the contributing zone upstream of the recharge zone. In order to include contributions from the drainage areas upstream of the recharge zone, it was necessary to modify the HSPF Pilot Recharge Models. The model modifications are described below.

4C.29.3.2 Baseline Conditions

To more accurately reflect baseline conditions and weather modification for the Blanco and Nueces Basins, the HSPF Pilot Recharge Models were modified in the following ways:

- Land segments were added upstream of the Nueces Recharge Basin (two segments) and Blanco Recharge Basin (one segment) to simulate upstream Nueces and Blanco watersheds contributing to the recharge zone(s). The Nueces Recharge Basin and Blanco Recharge Basin are shown in Figure 4C.29-2 and 4C.29-3, respectively.
- The Nueces River Basin period of record was extended from 1950 through 1998 to 1934 through 1998. Similarly, the Blanco River Basin historical simulation period of record was extended from 1956 through 1998 to 1934 through 1998. These adjustments were made to include in the model simulations the drought of record, which occurred in the 1950s.

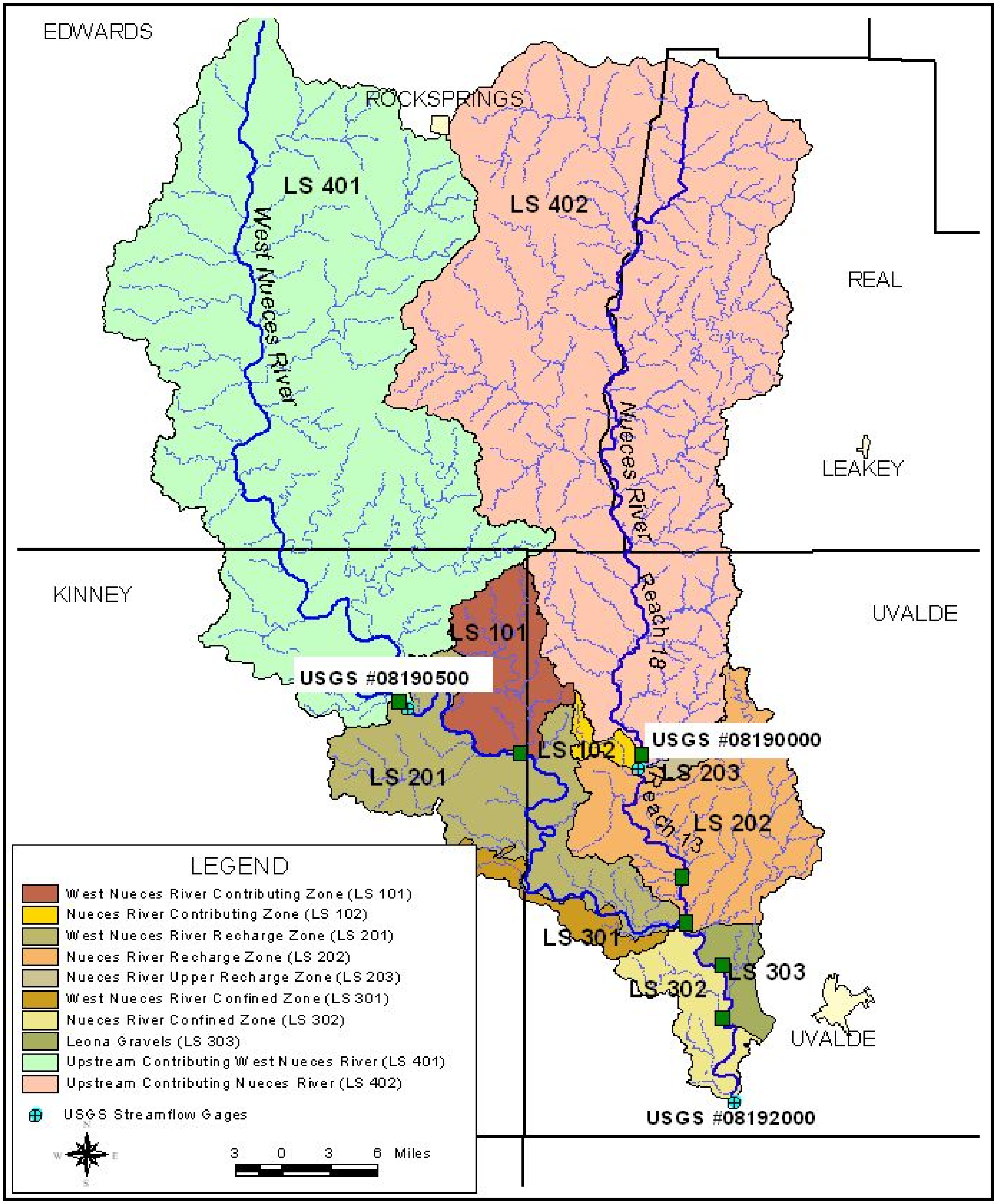


Figure 4C.29-2. Land Segments and River Reaches in the Nueces Recharge Basin

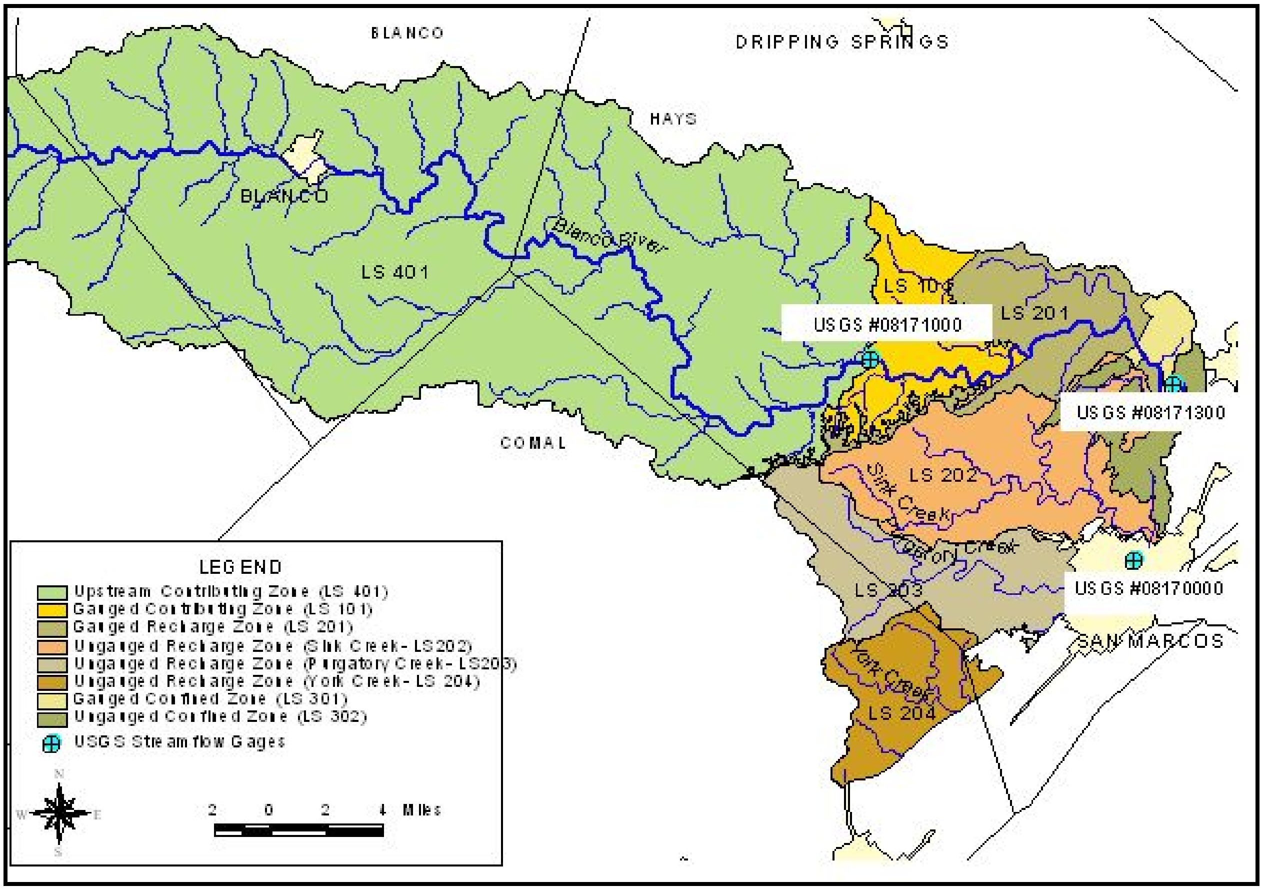


Figure 4C.29-3. Land Segments and River Reaches in the Blanco Recharge Basin

- The model parameter associated with lower zone evapotranspiration (LZETP), an index to the density of deep rooted vegetation, was changed from an annual average to a monthly distribution to account for seasonal variations (this subject is described in further detail in Section 4C.28).

Daily precipitation gage data were obtained from the National Weather Service (NWS), Edwards Aquifer Authority (EAA), and the USGS. The active precipitation stations used in the Pilot Study were used to extend the period of record for the Nueces River Basin (previously 1950-1998) and Blanco River Basin (previously 1956-1998) to include 1934-1998. For new land segments (two in Nueces River Basin and one in Blanco River Basin), the nearest active precipitation stations to the new land segments were used for daily precipitation data from 1934-1998.

Monthly gross water surface evaporation rates were obtained from the Texas Water Development Board (TWDB) for one degree quadrangles representative of the Nueces and

Blanco Recharge Basins for January 1934 through December 1998 for the two new land segments in Nueces River Basin and one new segment in the Blanco River Basin. For land segments contained in the original Pilot Models, the period of record was extended to January 1934. The procedure used to apply monthly evaporation quadrangle data to land segments, also used for the original Pilot Model study was based on an inverse relationship of distance from the center of the land segment to center of the evaporation quadrangle.

Precipitation and evaporation files were updated for the entire period of record (1934-1998) and new land segments with associated streams were added for upstream contributing zones, the new contributing zones were calibrated using historical USGS streamflow gage data. For the Nueces Basin, USGS #08190500- West Nueces at Bracketville was used to calibrate the West Nueces upstream contributing zone and USGS #08190000- Nueces at Laguna for the Nueces upstream contributing zone. For the Blanco Basin, USGS# 08171000- Blanco River at Wimberley located upstream of the recharge zone was used. Detailed calibration procedures and results are included in Appendix D. The new contributing zones for the Nueces and Blanco Basins were well calibrated to evaluate weather modification effects on recharge (Appendix D).

4C.29.3.2 Baseline + Weather Modification Conditions

The precipitation files used for the HSPF simulation were adjusted to account for weather modification. For this study, the amount of enhanced precipitation was calculated by considering (1) enhanced rainfall on a seasonal basis (based on cloud seeding during spring and summer months) and (2) an applying an estimated daily rate for increased precipitation to every day within the "optimal seeding" season. This enabled HSPF to model enhanced recharge of a long-term weather modification program considering that any day within the optimal seeding time was eligible for seeding provided preferable cloud conditions.

The following equation was used to evaluate expected daily increases in rainfall associated with weather modification for each day during the optimal season (April- September) for the entire simulation period from 1934-1998. Calculated enhanced rainfall was based on South Central Texas weather modification programs (i.e., EAA, STWMA, and SWTREA).

$$\frac{SE}{PREC} * \%Increase$$

Where:

SE = Seeded events with precipitation

PREC = Reported days with rainfall

% Increase = Average increase in precipitation attributed to weather modification

For example, during the 2002 STWMA program, 8 of 19 seeded events occurred on days with precipitation. A total of 29 days during the study period (in this case, April-October) had recorded rainfall, meaning that 8 out of 29 days had the potential of additional rainfall with weather modification. As mentioned earlier in Section 4C.29.2, the STWMA determined the average increase in precipitation attributed to weather modification is 7.3% over the Edwards Aquifer. Therefore, a 2% increase in rainfall occurred each day with the weather modification program.

$$\frac{8}{29} * 7.3\% = 2\%$$

Results from the EAA, STWMA, and SWTREA weather modification programs show precipitation increases ranging from 1 to 7%, based on atmospheric conditions and the frequency of cloud seedings. In April 2005, the Region L staff workgroup recommended that HSPF analyses include a 5% precipitation increase for the Nueces Recharge Basin and 6.5% precipitation increase for the Blanco Recharge Basin to simulate quantities of water available for recharge due to weather modification.

The modified HSPF Pilot Model contains a precipitation input file for each land segment in the Nueces (Figure 4C.29-2) and Blanco (Figure 4C.29-3) Recharge Basins. The precipitation files for the Nueces Basin were adjusted to simulate recharge resulting from weather modification by increasing precipitation by 5% for all days (April-September) when daily precipitation was $\neq 0$ and ≤ 2.5 inches. For land segments in the Blanco Basin (Figure 4C.29-2), the precipitation files were altered to simulate recharge resulting from weather modification by increasing precipitation by 6.5% for all days (April-September) when daily precipitation was $\neq 0$ and ≤ 3 inches. The seeding period and rainfall criteria were obtained from the 1999-2001 EAA Precipitation Enhancement Program, which included cloud seeding over the Nueces and Blanco Basin study areas.

4C.29.3.3 Recharge Enhancements (Attributable to Weather Modification)

After performing the HSPF simulations with and without weather modification, the difference in recharge was computed to quantify the enhanced recharge to the Edwards Aquifer for Nueces and Blanco Recharge Basins. The Nueces Recharge Basin provides recharge to the Edwards Aquifer from land segments (contributing and recharge zones), and their associated reaches. Recharge to the Edwards Aquifer from the Blanco Recharge Basin occurs from land segments (contributing and recharge zones), reaches, and flood retardation structures.

Recharge data from the HSPF model were evaluated for the entire 65 year simulation (1934-1998) and 5-year drought of record (1952-1956) to determine the amount of enhanced recharge with weather modification within land segments of the Nueces and Blanco Recharge Basins, as shown in Figures 4C.29-2 and 4C.29-3.

The Nueces Basin drought of record was from 1952 through 1956, according to NWS precipitation gauge data (16.8 inches of rainfall, based on 5-year precipitation average from 1934-1998). According to HSPF model results for the 65 year model simulation (1934-1998), on the watersheds shown in Figure 4C.29-2 is estimated to increase recharge in the Nueces Recharge Basin an average of 7,659 acft/yr (a 6.7% increase when compared to recharge without weather modification) as shown in Table 4C.29-4. For the 5-year drought period (1952-1956), the estimated increase in Edwards Recharge in the Nueces Recharge Basin is 2,639 acft/yr (or 6.3%).

Table 4C.29-4.
Summary of Nueces Basin Recharge
(with and without weather modification)

Nueces Recharge	***Baseline (without Weather Modification***	***Baseline + Weather Modification***	***Change Due to Weather Modification***	***% Change in Recharge***
Average Annual Recharge acft (1934-1998)	115,063 acft	122,722 acft	7,659 acft	6.7%
Average Drought Recharge acft (1952-1956)	41,829 acft	44,468 acft	2,639 acft	6.3%

The Blanco Basin drought of record was from 1952 through 1956, according to NWS precipitation gauge data (25.4 inches of rainfall, based on 5-year precipitation average from 1934-1998). According to HSPF model results for the 65 year model simulation (1934-1998), weather modification on the watersheds shown in Figure 4C.29-3 is estimated to increase recharge in the Blanco Recharge Basin an average of 4,250 acft/yr (a 6.4% increase when compared to recharge without weather modification) as shown in Table 4C.29-5. For the 5-year drought (1952-1956), the estimated increase in Edwards Recharge in the Blanco Recharge Basin is 1,093 acft/yr (or 9.2%).

Table 4C.29-5.
Summary of Blanco Basin Recharge
(with and without weather modification)

Blanco Recharge	***Baseline (without Weather Modification***	***Baseline + Weather Modification***	***Change Due to Weather Modification***	***% Change in Recharge***
Average Annual Recharge acft (1934-1998)	65,969 acft	70,219 acft	4,250 acft	6.4%
Average Drought Recharge acft (1952-1956)	11,877 acft	12,970 acft	1,093 acft	9.2%

The Nueces Recharge Basin receives a greater amount of enhanced recharge with weather modification because it has a larger watershed area (1,200,000 acres in the recharge portion of the Nueces Basin) than the Blanco Recharge Basin at 340,000 acres.

The monthly changes in Edwards Aquifer Recharge from the updated HSPF Pilot Recharge Model of the Nueces and Blanco Recharge Basins (with-without weather modification) are shown in Tables 4C.29-6 and 4C.29-7.

Even though precipitation was enhanced only during April-September, enhanced recharge in the Nueces and Blanco Recharge Basins frequency occurred outside those months. As seen in Tables 4C.29-6 and 4C.29-7, the amount of enhanced recharge October-March is significantly less than April-September and gradually decreases every month after September. This is primarily due to increased storage during the months with enhanced rainfall. The precipitation that enters the groundwater system (i.e. does not evaporate or become runoff) becomes storage and is slowly released (interflow) to the Nueces and Blanco river reaches, respectively. Other parameters that may affect enhanced recharge (to a lesser extent) during months when no enhanced precipitation occurs are delayed runoff and total actual evapotranspiration from land segments.

Table 4C.29-6.
Change in Historical Edwards Aquifer Recharge (with-without weather modification) from the HSPF Pilot Recharge Model of the Nueces Recharge Basin

Year	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	Grand Total
1,934	0	0	0	234	371	152	966	691	2,961	320	256	1,424	7,373
1,935	228	242	206	1,797	3,170	2,774	1,124	937	4,242	953	373	729	16,774
1,936	242	178	447	372	4,621	1,600	4,376	1,637	4,576	1,057	570	254	19,932
1,937	194	264	408	217	459	4,328	2,433	763	1,738	3,438	1,274	1,067	16,582
1,938	572	213	245	1,800	4,570	1,902	879	1,493	1,629	650	411	358	14,723
1,939	499	207	145	704	2,198	1,116	2,593	6,163	1,081	1,424	1,025	606	17,761
1,940	505	495	311	718	3,114	1,247	682	258	230	214	159	149	8,083
1,941	127	114	120	2,445	2,943	599	2,365	411	1,638	310	220	192	11,484
1,942	213	167	161	466	323	152	936	776	5,314	357	84	182	9,132
1,943	199	168	159	393	518	1,696	345	283	2,193	765	347	417	7,482
1,944	283	272	87	101	1,380	2,666	290	1,774	1,167	656	247	224	9,147
1,945	226	124	134	1,550	427	243	156	135	196	348	100	92	3,731
1,946	80	65	64	173	3,389	734	195	182	1,441	506	221	176	7,225
1,947	252	81	101	556	582	1,880	667	414	211	198	166	142	5,249
1,948	119	102	94	292	380	374	1,209	320	646	304	192	172	4,203
1,949	148	205	34	1,177	1,035	1,611	513	1,218	1,300	1,348	196	267	9,053
1,950	166	119	153	136	743	719	618	298	350	188	158	139	3,787
1,951	121	100	104	93	791	539	150	129	108	323	93	85	2,636
1,952	73	58	56	203	733	199	143	115	107	84	103	80	1,954
1,953	77	55	57	52	53	49	32	425	2,854	215	119	111	4,100
1,954	96	75	73	64	1,059	1,314	310	221	178	450	147	130	4,116
1,955	115	93	90	77	236	427	949	217	90	37	72	82	2,484
1,956	68	57	56	51	51	46	45	28	55	35	21	28	541
1,957	26	22	29	2,678	5,034	2,754	702	409	678	1,092	365	317	14,104
1,958	155	34	162	487	1,307	1,666	547	286	2,220	1,630	334	82	8,910
1,959	26	201	204	1,077	1,170	2,714	1,694	387	607	2,549	113	219	10,961
1,960	194	142	52	186	108	126	1,610	1,791	367	379	116	48	5,118
1,961	59	62	32	156	81	1,963	4,864	203	155	169	49	111	7,903
1,962	94	86	108	96	105	278	131	192	178	94	80	102	1,544
1,963	83	72	78	151	494	91	101	98	205	203	132	121	1,828
1,964	100	95	88	259	242	117	110	212	-1,815	1,012	418	267	1,105
1,965	172	52	97	484	3,482	259	142	151	338	179	270	268	5,896
1,966	213	172	98	2,312	907	209	126	1,677	1,846	516	304	263	8,642
1,967	244	190	184	388	171	155	167	372	2,526	940	473	102	5,911
1,968	247	223	79	533	4,046	501	602	246	485	209	304	156	7,632
1,969	214	144	143	149	1,477	508	189	566	703	3,353	583	484	8,514
1,970	126	709	-110	187	327	385	431	308	3,708	296	196	160	6,724
1,971	166	155	146	211	140	2,608	1,118	4,913	550	1,454	158	162	11,780
1,972	51	283	164	197	254	340	381	1,437	504	378	217	176	4,381
1,973	302	213	142	342	164	1,880	3,254	314	896	1,394	83	34	9,018
1,974	165	122	148	166	1,917	255	256	182	2,365	506	123	345	6,550
1,975	234	276	127	430	3,377	874	1,145	2,082	483	337	249	244	9,859
1,976	212	170	160	2,458	5,638	726	4,668	1,057	3,630	1,228	210	151	20,307
1,977	108	52	24	2,022	2,805	81	245	261	348	318	218	132	6,616
1,978	112	99	129	84	184	933	143	139	209	132	366	318	2,846
1,979	110	205	143	1,247	251	4,489	162	156	174	165	131	110	7,343
1,980	97	81	76	67	2,272	137	87	740	795	372	309	255	5,289
1,981	207	157	162	3,838	844	2,942	516	182	398	745	56	20	10,067
1,982	151	111	127	101	2,646	546	466	305	252	228	184	185	5,302
1,983	248	151	155	136	559	1,165	231	214	365	405	327	106	4,063
1,984	185	105	95	80	86	77	73	73	64	161	172	96	1,269
1,985	43	30	8	171	620	1,266	412	246	963	966	186	186	5,097
1,986	312	131	156	148	722	3,886	541	334	752	777	182	245	8,186
1,987	45	103	98	729	10,100	7,764	1,191	969	1,097	87	69	142	22,393
1,988	120	93	87	83	173	697	379	178	358	183	147	128	2,624
1,989	259	96	91	91	92	168	101	314	81	75	139	57	1,566
1,990	50	36	45	1,515	1,790	355	4,975	1,104	822	579	394	284	11,948
1,991	318	309	277	255	276	249	220	198	2,824	599	87	257	5,868
1,992	142	76	43	486	3,598	4,061	534	266	290	163	124	121	9,905
1,993	104	90	87	226	247	93	94	89	79	64	50	46	1,268
1,994	41	35	28	408	3,900	227	81	96	1,145	547	304	340	7,153
1,995	227	133	105	107	846	793	235	368	2,750	207	380	143	6,297
1,996	122	99	95	81	163	79	146	141	2,989	1,284	273	210	5,681
1,997	114	176	488	1,514	1,258	7,785	433	251	386	557	198	165	13,326
1,998	142	119	85	97	120	115	120	5,397	1,659	1,010	510	124	9,497
Average (1934-1998)	168	144	124	617	1,494	1,272	855	735	1,134	642	248	224	7,659
Drought Avg. (1952-1956)	86	68	66	89	426	407	296	201	657	164	92	86	2,639

Table 4C.29-7
Change in Historical Edwards Aquifer Recharge (With- Without Weather Modification) from the HSPF Pilot Recharge Model of the Blanco Recharge Basin

Year	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	Grand Total
1,934	0	0	0	572	308	35	106	111	197	76	198	541	2,145
1,935	150	63	98	407	2,868	1,913	642	196	3,648	223	31	238	10,478
1,936	12	30	1	319	1,731	383	1,134	452	1,905	312	161	84	6,524
1,937	49	0	138	182	256	1,395	528	214	175	920	156	291	4,304
1,938	43	19	0	2,556	916	717	528	29	120	86	227	84	5,325
1,939	287	174	179	352	743	572	1,853	533	347	336	318	130	5,825
1,940	183	263	146	648	583	2,664	302	182	117	113	191	14	5,405
1,941	24	57	-9	1,839	1,311	1,455	430	19	77	376	30	69	5,678
1,942	0	23	0	859	687	312	1,197	1,469	1,502	200	5	0	6,255
1,943	23	0	13	64	194	357	1,093	24	1,174	170	206	367	3,684
1,944	226	39	14	178	2,733	305	26	499	500	88	263	146	5,017
1,945	25	-3	3	387	182	489	240	15	75	393	40	67	1,913
1,946	-2	16	12	464	817	2,491	121	392	2,019	401	395	16	7,143
1,947	13	12	46	183	1,258	45	19	97	81	21	13	66	1,854
1,948	7	47	30	55	292	183	191	145	177	99	90	50	1,367
1,949	112	42	13	4,328	253	1,028	320	150	111	236	81	131	6,805
1,950	68	13	18	579	539	971	226	218	468	167	79	38	3,384
1,951	15	50	29	52	708	857	168	87	201	87	45	42	2,340
1,952	36	12	24	412	99	46	36	361	575	1	56	57	1,716
1,953	0	0	23	131	53	64	376	164	217	102	23	15	1,168
1,954	11	0	0	3	91	88	21	52	25	83	45	19	438
1,955	16	21	18	66	642	490	266	169	128	70	39	27	1,951
1,956	17	15	10	5	16	13	7	16	37	15	25	16	190
1,957	14	19	12	1,646	534	-366	71	33	3,326	332	-32	62	5,651
1,958	82	86	9	281	1,159	81	410	0	2,104	265	44	12	4,532
1,959	0	11	4	1,705	1,058	658	85	262	154	2,319	-65	-16	6,175
1,960	0	-9	11	405	2,088	1,199	188	543	120	533	-4	-9	5,066
1,961	1	-23	0	124	0	1,168	1,171	94	160	81	206	28	3,010
1,962	23	23	15	359	0	183	81	53	1,432	96	118	75	2,457
1,963	0	38	0	146	34	75	120	191	153	45	97	26	926
1,964	47	61	14	84	66	750	95	131	356	330	94	74	2,104
1,965	188	16	3	445	3,314	1,107	57	4	115	493	126	128	5,996
1,966	0	-11	0	397	983	184	0	136	491	78	0	0	2,257
1,967	0	0	20	18	174	59	86	60	1,206	190	180	9	2,000
1,968	28	0	0	595	907	938	226	0	310	96	114	248	3,461
1,969	61	84	51	1,140	1,227	511	2	42	195	359	35	66	3,772
1,970	0	1	2	504	1,443	118	0	84	952	488	0	0	3,593
1,971	0	25	1	25	227	197	67	1,626	1,097	756	612	107	4,739
1,972	2	23	0	38	81	107	147	458	171	133	194	0	1,354
1,973	107	95	12	1,535	271	1,164	2,919	304	1,799	-151	1	0	8,054
1,974	-16	-1	13	81	2,031	134	19	1,561	1,953	208	257	1	6,241
1,975	0	20	16	849	3,678	1,210	417	320	117	94	11	23	6,754
1,976	0	23	19	2,868	2,243	313	2,022	276	622	1,376	53	17	9,831
1,977	24	-19	0	2,563	518	324	0	0	0	2	13	0	3,426
1,978	0	26	42	117	162	431	31	269	2,249	24	1,051	-16	4,386
1,979	30	3	26	688	1,068	575	2,046	216	153	23	0	51	4,878
1,980	36	0	36	23	1,491	183	0	25	816	58	189	43	2,900
1,981	26	1	13	168	286	3,236	493	32	66	182	131	0	4,634
1,982	15	11	0	85	2,465	337	15	182	60	0	64	89	3,321
1,983	12	13	26	1	580	1,075	862	206	492	193	196	38	3,693
1,984	91	38	42	4	40	77	44	39	22	31	0	0	427
1,985	4	0	0	459	447	3,835	2,666	2	536	422	539	-12	8,897
1,986	23	-14	11	53	2,219	1,682	11	19	838	1,103	29	104	6,079
1,987	19	69	3	122	2,586	2,516	637	4	51	26	243	23	6,299
1,988	0	0	0	101	1,114	228	316	52	11	28	0	3	1,854
1,989	22	11	64	319	1,192	499	0	28	35	35	30	9	2,244
1,990	27	23	4	444	1,538	194	952	47	187	196	201	0	3,814
1,991	225	10	0	1,488	947	1,288	436	272	1,389	126	114	1,158	7,453
1,992	-112	-21	-35	533	2,626	1,364	251	120	36	0	43	27	4,832
1,993	15	0	19	284	1,356	1,197	0	0	0	26	0	0	2,898
1,994	46	0	0	215	1,473	358	0	49	483	902	2	74	3,601
1,995	2	0	0	753	3,393	324	101	11	429	71	190	11	5,285
1,996	1	6	10	92	101	531	118	1,594	1,299	219	381	232	4,581
1,997	19	102	42	1,731	1,239	4,554	38	210	61	216	124	79	8,414
1,998	66	-10	0	56	19	0	74	519	2,111	574	17	18	3,444
Average (1934-1998)	38	25	20	587	1,010	792	417	241	647	264	128	81	4,250
Drought Avg (1952-1956)	16	9	15	124	180	140	141	152	196	54	38	27	1,093

4C.29.3.4 Increase in Sustained Yield (attributable to Weather Modification)

The recharge enhancements attributable to weather modification for the Nueces and Blanco Recharge Basins were processed with GWSIM4 to determine increases in sustained yield from the Edwards Aquifer. Sustained yield of the Edwards aquifer is defined as the amount of pumpage from the Edwards such that a simulated minimum flow at Comal Springs is protected during the drought of record (in this case, 60 cfs). The additional water supply is based on increases in sustained yield from the Edwards Aquifer. Weather modification evaluated with 5 percent precipitation increase in the Nueces Recharge Basin and 6.5 percent precipitation increase in the Blanco Recharge Basin is calculated to increase sustained yield by 1,916 acft/yr and 488 acft/yr, respectively. The Nueces Basin has greater water supply benefits with a brush management program due to its higher average annual recharge as compared with the Blanco Basin.

4C.29.4 Environmental Effects of Weather Modification

Although cloud seeding weather modification is not a new technique, the effectiveness of weather modification has been difficult to measure. Since Texas has established a permit procedure, administered by TCEQ, data are being collected for a more scientific study of cloud seeding effectiveness and management. Originally conceived as a means to end droughts, weather modification is now considered a long-term water augmentation strategy for freshwater supplies.[17] The amount of silver iodide and calcium chloride used during a seeding event is negligible and too dispersed to have a measurable effect on the environment. Safe handling and storage of these materials prior to dispersal are a larger concern. Both are normally used in industrial applications and printing. Therefore, procedures for handling and storing silver iodide are well documented. Assuming that increased rainfall in the seeded area does not result in decreased rainfall elsewhere, it is difficult to see what adverse environmental impact would result. The benefits resulting from cloud seeding in the South Central Texas Region may include improvements in environmental and economic conditions. Environmental conditions in a stream, estuary, or lake can be improved by increased freshwater flows and the improvements can be measured using water quality parameters and aquatic life. Economic conditions can be improved by increasing crop production, by increasing animal production as a result of increasing the food supply, and by increasing ground and surface water supplies. Increasing water supplies can further improve economic conditions by affecting recreation, agriculture, municipal, and industrial activities in beneficial ways.

[17] Bomar, George, TCEQ Senior Meteorologist, Austin, Texas.

4C.29.5 Engineering and Costing of Weather Modification

According to Mike Mahoney at Evergreen UWCD, the total cost of the program for STWMA's 10-county region (6,603,520 acres) was $428,067 in 2003, including $215,387 in initial capital costs and $212,680 Operations and Maintenance costs, or $0.065 per acre. For 2004, the Edwards Aquifer Authority contracted SWTREA as part of their Precipitation Enhancement Program to perform cloud-seeding over Uvalde County at an annual cost of $37,951 or $0.04 per acre. The Authority also contracted STWMA to perform cloud seeding in Bandera, Bexar, and Medina Counties at an annual cost of $86,825 or approximately $0.04 per acre.

For the Nueces Recharge Basin, the total annual cost for a weather modification program for Edwards, Real, Kinney, and Uvalde Counties (3,693,440 acres) is estimated at $147,740, assuming an annual cost of $0.04 per acre. For an increased sustained yield of 1,916 acft/yr from the Edwards Aquifer (Section 4C.29.3.4), the unit cost is estimated at $77 per acft. This cost is based on increases in sustained yield from the Edwards Aquifer and is not necessarily applicable to other basins.

For the Blanco Recharge Basin, the total annual cost for a weather modification program for Blanco and Hays Counties (901,120 acres) is estimated at $36,050, assuming an annual cost of $0.04 per acre. For an increased sustained yield of 488 acft/yr from the Edwards Aquifer (Section 4C.29.3.4), the unit cost is estimated at $74 per acft. This cost is based on increases in sustained yield from the Edwards Aquifer and is not necessarily applicable to other basins.

4C.29.6 Implementation Issues

Weather modification in the form of cloud seeding is a beneficial, but uncertain, source of usable water. However, data are not adequate to quantify firm yield in terms of a measurable and dependable regional water supply option.

One important potential benefit of cloud seeding is that a part of the agricultural water supply needs (irrigated and dryland crops and rangelands) could be met. For example, higher rainfall would lower the quantities of irrigation water that has to be withdrawn from the aquifers and streams of the South Central Texas Region, and dryland production would benefit from increased rainfall. This could be a significant water supply option for agricultural uses. Over a sufficient period, agricultural production data could be developed to demonstrate that crop yield, animal production, and other measurable agricultural parameters have increased as compared to the same data prior to beginning the cloud seeding program. For a relatively minor cost, cloud seeding could meet some of the agricultural needs, as well as contribute to aquifer recharge and streamflows of the region.

Evaluations of this regional water management option for the Nueces and Blanco Recharge Basins are provided in Tables 4C.29-8 and 4C.29-9.

Table 4C.29-8.
Evaluation Summary of Weather Modification to Enhance Water Supply Yield-Nueces Recharge Basin

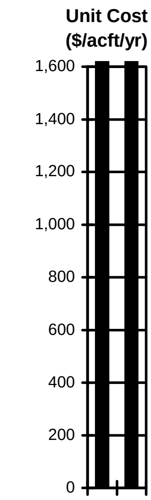
Impact Category	***Comment(s)***
a. Water Supply 1. Quantity 2. Reliability 3. Cost of Treated Water	 1. Sustained yield increase of 1,916 acft/yr from Edwards Aquifer 2. Good reliability, if good timing is achieved. 3. Low cost; $77 per acft
b. Environmental factors 1. Instream flows 2. Bay and Estuary Inflows 3. Wildlife Habitat 4. Wetlands 5. Threatened and Endangered Species 6. Cultural Resources 7. Water Quality	 1. May slightly increase instream flows. 2. May slightly increase bay and estuary flows. 3. None or low impact. 4. None or low impact. 5. None or low impact. 6. None or low impact. 7. None or low impact.
c. Impacts to State water resources	• No apparent negative impacts on other water resources • Benefit to Edwards Aquifer water resources due to increased water for recharge.
d. Threats to agriculture and natural resources in region	• Potential benefit to farmers and ranchers through increased rainfall • Potential threats due to limited risk of increased flooding
e. Recreational impacts	• None
f. Equitable Comparison of Strategies	• Cost based on weather modification programs in South Central Texas Region
g. Interbasin transfers	• Not applicable
h. Third party social and economic impacts from voluntary redistribution of water	• Not applicable
i. Efficient use of existing water supplies and regional opportunities	• Improvement over existing conditions
j. Effect on navigation	• None
k. Consideration of water pipelines and other facilities used for water conveyance	• None

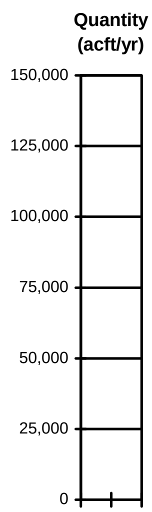
Table 4C.29-9.
Evaluation Summary of Weather Modification to Enhance Water Supply Yield-Blanco Recharge Basin

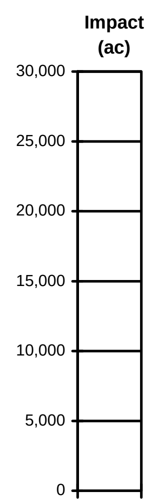
Impact Category	***Comment(s)***
a. Water Supply	
1. Quantity	1. Sustained yield increase of 488 acft/yr from Edwards Aquifer
2. Reliability	2. Good reliability, if good timing is achieved.
3. Cost of Treated Water	3. Low cost; $74 per acft
b. Environmental factors	
1. Instream flows	1. May slightly increase instream flows.
2. Bay and Estuary Inflows	2. May slightly increase bay and estuary flows.
3. Wildlife Habitat	3. None or low impact.
4. Wetlands	4. None or low impact.
5. Threatened and Endangered Species	5. None or low impact.
6. Cultural Resources	6. None or low impact.
7. Water Quality	7. None or low impact.
c. Impacts to State water resources	• No apparent negative impacts on other water resources • Benefit to Edwards Aquifer water resources due to increased water for recharge.
d. Threats to agriculture and natural resources in region	• Potential benefit to farmers and ranchers through increased rainfall • Potential threats due to limited risk of increased flooding
e. Recreational impacts	• None
f. Equitable Comparison of Strategies	• Cost based on weather modification programs in South Central Texas Region
g. Interbasin transfers	• Not applicable
h. Third party social and economic impacts from voluntary redistribution of water	• Not applicable
i. Efficient use of existing water supplies and regional opportunities	• Improvement over existing conditions
j. Effect on navigation	• None
k. Consideration of water pipelines and other facilities used for water conveyance	• None

(This page intentionally left blank.)

2006 South Central Texas Regional Water Plan
Water Management Strategy Summary Sheet







Name: Rainwater Harvesting

Description: Collecting rainfall from roofs and storing the runoff to meet daily household water needs.

***Decade Needed*:** 2000 – 2060: Applicable to areas of the region that depend upon the Trinity Aquifer.

Cost, Quantity of Water, and Land Impacted

Unit Cost of Water:	**$17,982 to $10,320**	**$/acft/yr**	**Treated Water on Site**
Quantity of Water:	**0.0574 to 0.10**	**acft/yr**	**Per Household**
Land Impacted:	**0**	**acres**	

Additional Considerations per Regional Water Planning Guidelines

Environmental Factors:

No significant effects.

Impacts on Water Resources:

None anticipated.

Impacts on Agricultural & Natural Resources:

None anticipated.

Other Relevant Factors per SCTRWPG:

With financing for 30 years, may be able to include cost of installation in home mortgages.

Comparison of Strategies to Meet Needs:

Costs vary by site, but are relatively high in comparison to conventional water supply strategies. Based upon $14,213 installed cost and no operating expenses.

Interbasin Transfer Issues:

Not applicable.

Third-Party Impacts of Voluntary Transfers:

Not applicable.

Regional Efficiency:

This on-site water supply technology contributes to meeting municipal needs in remote areas that cannot be easily and economically served via other water management strategies.

Water Quality Considerations:

None anticipated with proper rainwater harvesting system operation and maintenance.

(This page intentionally left blank.)

4C.30 Rainwater Harvesting

4C.30.1 Description of Water Management Strategy

In several parts of the South Central Texas Regional Planning Area, rainwater harvesting systems have been constructed with success. This water management strategy will consider the capture and storage of rainwater from roofs of homes for both potable and non-potable purposes for dwellings located in areas that are presently supplied by the Trinity Aquifer (parts of Uvalde, Medina, Bexar, Kendall, Comal, and Hays Counties), which is experiencing water level declines and causing local residents to consider development of additional water supplies.[1]

A rainwater harvesting system collects water as it runs off roofs into gutters that convey it into a cistern or storage tank. This harvested rainwater can then be used for household potable use, landscape irrigation, or other uses. For most uses of water derived from rainwater harvesting systems, the basic system components are as follows:

- Catchment Area/Roof;
- Gutters and Downspouts;
- Leaf Screens and Roof Washers;
- Storage Facilities (Cisterns, Man-made Aquifers, and Drumsticks);
- Conveyance Facilities; and
- Water Treatment.

Each system component is described briefly below.

Catchment Area: The catchment area is the surface on which the rain that will be collected falls. This report will focus on roofs as catchment areas although channeled gullies along driveways or other impermeable surfaces may be used as catchment areas for water to be used for non-potable purposes, such as irrigation.

Gutters and Downspouts: Gutters are the components that catch the rain from the roof catchment surface, and downspouts transport the runoff to a cistern, manmade aquifer, or a "drumstick" for storage.

Leaf Screens and Roof Washers: Leaf screens of one-fourth inch mesh wire in a metal frame should be installed along the entire length of the gutters to keep leaves and debris from entering the storage components. In addition, a roof washer system is needed to collect and dispose of the "first flush" of water from a roof to divert dirt, debris, and contaminants, such as

[1] Although the costs may be applicable in other parts of the South Central Texas Region, the precipitation information is only applicable in the areas overlying the Trinity Aquifer.

bird droppings from the system. A simple roof washer can be made using a 6 to 8 inch diameter pipe (PVC can be used) which has a valve and clean out at the bottom. This type of roof washer extends from the gutter to the ground. The gutter downspout and top of the roof washer pipe are fitted and sealed so water will not flow out the top. Once the roof washer pipe has filled with "first flush" runoff, the remainder of water flows to the downspout and is conveyed to the storage component (cistern, man-made aquifer, or drumstick).

Storage Facilities: The cistern, which is a storage vessel designed to store accumulated rainfall for use during periods of low or no rainfall, represents the largest investment in a rainwater harvesting system and may be placed above or below ground. Its construction may use a variety of materials to fit different needs and budgets.

Another potential storage component is a manmade aquifer. A manmade aquifer can be constructed by lining an excavation with a pond liner and backfilling it with round, uniformly graded gravel. Depending on the nature of the soil and the liner, one or two layers of geotextile may be required to protect the liner. A geotextile layer is placed over the gravel and then a lawn, parking lot, or tennis court can be constructed on top. The capacity of a manmade aquifer is determined by the volume of the excavation and the amount of void space between the stones and can be estimated by calculating 40 to 50 percent of the gross volume within the liner. In the South Central Texas Planning Area, a manmade aquifer would require large excavations, which may not be feasible for existing facilities with outdoor structures or trees with extensive root systems.[2]

The drumstick storage method is constructed by auguring a deep hole and under-reaming it. A corrugated metal pipe with a welded end cap is placed into the hole and grouted in place. Although not as cost-effective as the manmade aquifer, the drumstick is more suitable when space is limited. For example, if a site is covered with trees that have canopies that nearly touch, the drumstick can be installed between the drip lines of adjacent trees in order to avoid root damage.[3]

Conveyance Facilities: The conveyance facilities transport the stored water to its point of use. The conveyance facilities may be a simple pipe in gravity feed systems, although most systems will also require a pump to maintain proper pressure in faucets.

[2] Givler, L. David, "Storage Innovations: Methods for Making Rainwater Harvesting More Cost-Effective."
[3] Ibid.

Water Treatment: If water is used inside the house, water treatment facilities are needed, and the extent of treatment depends upon the nature of the use of the water. For example, potable use requires more treatment than use for toilet flushing. The water treatment facilities may be simple filters or a more complex system including disinfection and buffering.

4C.30.2 Available Yields for Rainwater Harvesting Systems

The amount of rainwater that can potentially be harvested for later use depends on the size and texture of the catchment area on which the rain falls and quantities of rainfall. Each of these factors is explained below.

To determine the square footage of a catchment area of a building, use only the building's footprint. The actual area of roof material will be greater due to the roof slope. However, the slope does not affect the amount of rainfall falling on the roof. A smoother, cleaner, and more impervious roofing material contributes to better water quality and greater quantity. While loss may be negligible for pitched metal roofs, concrete or asphalt roofs average slightly less than 10 percent loss, and built up tar and gravel roofs average a maximum of 15 percent loss. Losses can also occur in the gutters and storage. Regardless of roofing material, many designers assume as much as a 25 percent loss of annual rainfall.[4]

That part of the South Central Texas Region located over the Trinity Aquifer has historically received between 24 inches and 36 inches of rain per year. A catchment area of 1,500 square feet receiving 24 inches of rainfall per year could collect as much as 16,830 gallons of water, while the same catchment area receiving 36 inches of rainfall per year could collect as much as 25,245 gallons of water (Table 4C.30-1). A catchment area of 2,500 square feet receiving 24 inches of rainfall per year could collect as much as 23,375 gallons of water, while the same catchment area (2,500 square feet) receiving 36 inches of rainfall per year could collect as much as 42,075 gallons of water per year (Table 4C.30-1).

A water conserving household that has low-flow plumbing fixtures such as 1.6 gallons-per-flush toilets and 2.75 gallons-per-minute shower heads, now required by the Texas Plumbing Fixtures Act of 1991, might use 55 gallons or less of water per day per person for indoor purposes. However, for the purposes of designing a rainwater collection system, a more conservative figure of 75 gallons per person per day for indoor use is advised to ensure adequate

[4] Texas Water Development Board and the Center for Maximum Potential Building Systems, "Texas Guide to Rainwater Harvesting." 1996.

year-round indoor water supply.[5] Given this assumption, average daily indoor use would be about 200 gallons for a family averaging 2.62 persons per dwelling, which is the average of cities located in the Trinity Aquifer area of the South Central Texas Region (2.62 persons x 75 gallons/day = 196, rounded to 200). The longest period without rainfall over the past 50 years was approximately 65 days for this part of the South Central Texas Planning Region.[6] If the household's average daily water use is multiplied by 100 (giving a safety factor of 35 days over the longest period without rainfall of the last 50 years), the total amount of storage capacity required to provide water through a period of no rainfall lasting 100 days would be 20,000 gallons. It can be seen from Table 4C.30-1 that a home having 2,500 square feet of catchment area may be able to provide this amount of water, while a home having 1,500 square feet of catchment area would not be able to rely solely on a rainwater harvesting system to supply its occupant's water needs during a period of 100 days without rainfall.

Since the largest need for non-potable water for uses such as lawn watering generally occurs during the time of lowest rainfall and highest temperature, a rainwater harvesting system designed to meet these needs would have to capture water prior to the summer irrigation season of the study area. Thus, the size of the rainwater storage system may be prohibitive for using rainfall as the sole source of water for lawn irrigation in large or water intensive landscapes. This can be illustrated by the following example. The landscaped area to be irrigated in this example consists of 2,500 square feet, and it has been determined through consultation with landscape specialists that the plants should receive a minimum of one inch of rain per week to be healthy from June through September.

The 2,500 square feet of landscaped area will require 1,558 gallons of water to equal one inch of rain per week (Table 4C.30-2), so for 16 weeks (June through September) the water requirement will be 24,928 gallons (16 weeks x 1,558 gallons). In this example, it is assumed that only half of the average summer rainfall will occur, thus providing a safety factor. For the City of Boerne, the total average rainfall for June through September is approximately 12.46 inches; thus the assumption is that only 6.23 inches of rain will actually fall during the

[5] Ibid.
[6] Doxsey, W. Laurence, "Rainwater Harvesting."

Table 4C.30-1.
Annual Rainfall Yields in Gallons for
Various Roof Sizes and Rainfall Amounts*

Roof Size (square feet)	***Annual Rainfall (inches)***					
	20	***24***	***28***	***32***	***36***	***40***
1,000	9,350	11,220	13,090	14,960	16,830	18,700
1,100	10,285	12,342	14,399	16,456	18,513	20,570
1,200	11,220	13,464	15,708	17,952	20,196	22,440
1,300	12,155	14,586	17,017	19,448	21,879	24,310
1,400	13,090	15,708	18,326	20,944	23,562	26,180
1,500	14,025	16,830	19,635	22,440	25,245	28,050
1,600	14,960	17,952	20,944	23,936	26,928	29,920
1,700	15,895	19,074	22,253	25,432	28,611	31,790
1,800	16,830	20,196	23,562	26,928	30,294	33,660
1,900	17,765	21,318	24,871	28,424	31,977	35,530
2,000	18,700	22,440	26,180	29,920	33,660	37,400
2,100	19,635	23,562	27,489	31,416	35,343	39,270
2,200	20,570	24,684	28,798	32,912	37,026	41,140
2,300	21,505	25,806	30,107	34,408	38,709	43,010
2,400	22,440	26,928	31,416	35,904	40,392	44,880
2,500	23,375	28,050	32,725	37,400	42,075	46,750

* Table includes a 25 percent loss factor due to roofing material texture, evaporation, and inefficiencies in the collection process.

lawn irrigation season (Table 4C.30-3). Pro-rated from Table 4C.30-1, 6.23 inches of rainfall would result in approximately 5,825 gallons of water captured from a 1,500 square foot roof for the period June through September. The amount of water that needs to be collected for landscape irrigation can be found by subtracting the rainfall (5,825 gallons) from the required amount (24,928 gallons), and in this case is found to be 19,103 gallons. This difference is the amount of rainwater that must be in storage prior to June for use as landscape irrigation water if actual rainfall is equal to one-half of the average rainfall for the June through September period.

If this amount of storage is added to the amount required for potable uses, the required capacity of the system would be about 39,103 (20,000 for potable use from Page 4C.30-4 plus 19,103) gallons. In instances where there is a limiting factor in the capacity of a rainwater harvesting system, such as cost or space, a smaller system could perhaps be installed and used entirely for either potable or non-potable uses. For example, a rainwater harvesting system used in conjunction with water received from a municipal water system might fulfill a part of outdoor water requirements such as lawn and garden irrigation. Similarly, a rainwater harvesting system used in conjunction with an existing well could augment or enhance the quality of mineralized well water for purposes such as washing, or provide back-up water when underground water sources are low. However, in the Trinity Aquifer part of the South Central Texas Region, a larger rainwater harvesting system would be capable of providing most of the water needs for a household, although significant cost in constructing the system would be involved.

Table 4C.30-2.
Annual Rainfall Yield in Gallons for
Various Landscape Sizes for Rainfall Events

Landscaped Area (square feet)	***Rainfall (inches)***								
	0.25	***0.50***	***0.75***	***1.00***	***2.00***	***3.00***	***4.00***	***5.00***	***6.00***
1,000	156	312	468	623	1,247	1,870	2,493	3,117	3,740
1,100	171	343	514	686	1,371	2,057	2,743	3,428	4,114
1,200	187	374	561	748	1,496	2,244	2,992	3,740	4,488
1,300	203	405	608	810	1,621	2,431	3,241	4,052	4,862
1,400	218	436	655	873	1,745	2,618	3,491	4,363	5,236
1,500	234	468	701	935	1,870	2,805	3,740	4,675	5,610
1,600	249	499	748	997	1,995	2,992	3,989	4,987	5,984
1,700	265	530	795	1,060	2,119	3,179	4,239	5,298	6,358
1,800	281	561	842	1,122	2,244	3,366	4,488	5,610	6,732
1,900	296	592	888	1,184	2,369	3,553	4,737	5,922	7,106
2,000	312	623	935	1,247	2,493	3,740	4,987	6,233	7,480
2,100	327	655	982	1,309	2,618	3,927	5,236	6,545	7,854
2,200	343	686	1,029	1,371	2,743	4,114	5,485	6,857	8,228
2,300	358	717	1,075	1,434	2,867	4,301	5,735	7,168	8,602
2,400	374	748	1,122	1,496	2,992	4,488	5,984	7,480	8,976
2,500	390	779	1,169	1,558	3,117	4,675	6,233	7,792	9,350

Table 4C.30-3.
Monthly Average
Rainfall in Boerne

Month	*Average Rainfall (inches)*	*Month*	*Average Rainfall (inches)*
January	1.83	July	2.17
February	2.13	August	2.73
March	1.76	September	3.53
April	2.89	October	3.52
May	4.52	November	2.39
June	4.03	December	1.83

For purposes of illustrating the applicability of the rainwater harvesting option, it was assumed that this option would only be relevant for the counties that rely upon the Trinity Aquifer. Table 4C.30-4 summarizes the estimated number of households potentially applicable to this option.

Table 4C.30-4.
Number of Potential Applications
of Rainwater Harvesting in Region

County	*Potential Households for Rainwater Harvesting*					
	2010	*2020*	*2030*	*2040*	*2050*	*2060*
Bexar[1]	3,175	3,614	4,006	4,325	4,611	4,865
Comal[2]	4,211	5,715	7,427	9,104	10,841	12,710
Hays[2]	4,677	6,719	8,323	9,929	11,842	13,336
Kendall[2]	1,390	1,957	2,558	3,062	3,475	3,879
Medina[2]	1,816	2,133	2,429	2,684	2,933	3,156
Uvalde[2]	1,113	1,223	1,315	1,387	1,435	1,471

[1] Assumes Northern Bexar County only. One-half percent of projected county population and 2.57 persons per household, which is the average of all cities in the region.
[2] Assumes 10 percent of projected county population and 2.57 persons per household, which is the average of all cities in the region.

An estimate of the unit (per household) annual yield can be made from average rainfall in each county and the yield rates in Table 4C.30-1, assuming an average roof footprint size. Table 4C.30-5 shows the annual per household yield for each county.

Table 4C.30-5.
Estimated per Household Yield from Rainfall Harvesting

County	Annual Rainfall (inches)	Harvesting Yield Based on 2,500 Square Feet of Roof Footprint	
		gallons/yr	acft/yr
Bexar	29.1	34,011	0.10
Comal	33.6	39,270	0.12
Hays	34.3	40,088	0.12
Kendall	32.2	37,634	0.12
Medina	28.5	33,309	0.10
Uvalde	24.1	28,167	0.09

From the average annual yield for each county and the estimated number of households in each county for each incremental planning year, an estimate of the total yield can be made (Table 4C.30-6).

Table 4C.30-6.
Total Estimated Yield from
Rainwater Harvesting in Region

County	Year					
	2010 (acft/yr)	2020 (acft/yr)	2030 (acft/yr)	2040 (acft/yr)	2050 (acft/yr)	2060 (acft/yr)
Bexar	317	361	401	432	461	487
Comal	505	686	891	1,092	1,301	1,525
Hays	561	806	999	1,192	1,421	1,600
Kendall	167	235	307	367	417	466
Medina	182	213	243	268	293	316
Uvalde	100	110	118	125	129	132
Totals	1,833	2,412	2,959	3,477	4,023	4,526

4C.30.3 Environmental Issues

No apparent negative impacts on the environment resulting from rooftop rainwater harvesting are expected. Traditionally, impervious cover results in excessive run-off in storm events, which can lead to erosion, flooding, and contamination of lakes and streams from nonpoint source pollution. Rooftop rainwater harvesting would be expected to mitigate these potential effects by capturing and storing rooftop run-off. Demand on the regional aquifer and surface water resources would be decreased and the minimal construction procedures would be of negligible consequence.

4C.30.4 Approximate Cost of a Rainwater Harvesting Systems in the Region

A rainwater harvesting system designed as an integrated component in the construction of a new building is generally more cost-effective than retrofitting a system onto an existing building. This is because many of the shared costs (roof and gutters) can be designed to optimize system performance. In addition, the investment can be amortized over time.

Rainwater harvesting systems designed to fulfill all the water needs of a home can be as costly, and perhaps more expensive, than the cost of drilling a conventional well, which ranges from approximately $5,000 to $15,000 in the Trinity Aquifer area.[7,8] However, with careful planning and design, the cost of a rainwater system can be less than the cost of a well in some cases – especially if the well water must be softened and treated to remove dissolved minerals, and the rainwater system is owner-built, which is a viable option for people with available time and basic skills.

Many factors affect the cost of a rainwater harvesting system, such as the capacity of the system, construction material, method of storage, and size of pump needed to supply adequate pressure for faucets. However, it is hard to generalize about the cost of a rainwater harvesting system because each system will be unique, and because of the large number of options for the construction material and type of cistern, which is the largest cost component in a rainwater harvesting system. Cost estimates range from $1.65 per gallon for a 4,000 gallon capacity underground concrete cistern to $1.20 per gallon for a 25,000 gallon capacity underground concrete cistern, while the costs for an aboveground fiberglass cistern range from $1.12 for a 4,000 gallon capacity tank to $0.65 for a 25,000 gallon capacity tank (Table 4C.30-7).[9] New methods for water storage such as the manmade aquifer and drumstick may prove more cost-effective (Table 4C.30-7). According to the Texas Water Development Board, most rainwater

---

[7] Texas Water Development Board (TWDB) and the Center for Maximum Potential Building System, "Texas Guide to Rainwater Harvesting," 1996.
[8] Environmental Home Program, "Why Harvest Rainwater?."
[9] Givler, L. David, "Storage Innovations: Methods for Making Rainwater Harvesting More Cost-Effective."

harvesting systems have an approximate construction cost of $1.08 per gallon of collection capacity.[10]

In order to determine a cost per unit of yield for comparison with other options, certain assumptions are required for storage capacity and other engineering features. In the following example, costs are estimated for a rainfall harvesting facility to only irrigate landscaping during a prolonged period of no rainfall. Therefore, the tank size should be approximately equal to the volume of water needed for 1.0 inch of rainfall per week for 12 weeks for a landscaped area of 2,500 square feet. Referring to Table 4C.30-2, this volume of water would be 1,558 gallons per week, or about 18,700 gallons per season. Another assumption is that the irrigation system is already installed and that the storage tank and irrigation pump or distribution header (if it is a gravity system) are located near the home. The assumptions are summarized as follows:

Table 4C.30-7.
Storage System Cost Comparison

Capacity (Gallons)	Underground Concrete (per gallon)	Aboveground Fiberglass (per gallon)	Drumstick[1] (per gallon)	Manmade Aquifer (per gallon)
4,000	$1.65	$1.11	$1.94	$0.68
15,000	$1.32	$0.70	$0.90	$0.68
25,000	$1.20	$0.65	N/A	$0.65

[1] No price is provided for the 25,000 gallon drumstick option because such capacity may not be feasible with a single installation.

Source: Givler, L. David, "Storage Innovations: Methods for Making Rainwater Harvesting More Cost-Effective."

- Storage Tank Capacity - 20,000 gallons
- Piping from roof to tank – 25 feet of 4-inch diameter PVC pipe
- Piping from tank to irrigation system – 10 feet of 2-inch PVC pipe

Costs can be estimated from Table 4C.30-7 plus an allowance for the pipe, connections, and valves. The costs are summarized in Table 4C.30-8. For an installation cost of $14,213 for this example and assuming no maintenance costs and 6 percent financing for 30 years, the annual cost is $1,032. For a yield of 0.0574 acft/yr (18,700 gallons), the cost is estimated to be $55.19 per 1,000 gallons of yield ($17,982 per acft).

[10] TWDB and the Center for Maximum Potential Building Systems, Op. Cit., 1996.

Another generalized approach to estimating the cost of rainfall harvesting is presented in Table 4C.30-9. In this table the data from Table 4C.30-5 are used with the same annual cost in the example above. The yields presented in Table 4C.30-5 and shown below represent the total annual capture from a 2,500 square foot roof footprint for each county addressed.

4C.30.5 Implementation Issues

The unit costs presented above are consistent with costs of actual installations. The relatively small yield, which can be developed from rainfall harvesting, makes the unit costs quite high in relation to unit costs for public water systems of cities of the area. The maximum annual water quantity from a residence in the region is 40,088 gallons for a roof footprint of 2,500 square feet (Table 4C.30-5). This is the equivalent of less than 43 gallons per person per

Table 4C.30-8.
Summary of Rainfall Harvesting Example Installation

Component	Unit Cost	Total Cost
20,000-gal above ground fiberglass storage tank	$0.70	$14,040
25 feet of 4" PVC, installed	$2.16	$54
10 feet of 2" PVC	$1.08	$11
Appurtenances	—	$108
Total		$14,213

Table 4C.30-9.
Estimated Annual Cost of Rainfall Harvesting

	Annual Yield*		Annual Unit Cost	
County	gallons/year	acft/year	$ per 1,000 gallons	$ per acft
Bexar	34,011	0.10	$29.47	$10,022
Comal	39,270	0.12	$25.52	$8,352
Hays	40,088	0.12	$25.00	$8,353
Kendall	37,634	0.12	$26.63	$8,352
Medina	33,309	0.10	$30.08	$10,022
Uvalde	28,167	0.09	$35.58	$11,136

* See Table 4C.30-5. Based on 2,500 square feet of roof footprint and average annual rainfall in each county.

day of water supply. However, for low density housing areas, and widely spaced individual housing units, it may be an acceptable water supply method. Furthermore, an installed rainwater harvesting system could perhaps be supplemented during long dry periods by hauling treated water from a nearby public supply. However, obviously water and tank trucks from a nearby public supply would have to be available.

Another implementation issue involves the health and safety of the users. The State of Texas does not currently regulate the indoor or outdoor household use of rainwater unless the system is backed up by publicly supplied waterlines. If a backup system is used, to avoid any cross-connections, an air gap must exist between the public water and rainwater. In addition to this requirement, the Health Department requires that all cisterns be covered so that the rainwater system does not contribute to mosquito breeding.

Table 4C.30-10.
Evaluations of Rainwater Harvesting
to Enhance Water Supply Yield

Impact Category	*Comment(s)*
a. Quantity reliability and cost of treated water	• Quantity directly dependent on rainfall • Extremely high unit cost
b. Environmental factors	• none
c. State water resources	• No apparent negative impacts on other water resources
d. Threats to agriculture and natural resources in region	• none
e. Recreational	• none
f. Comparison and consistency equities	• Cost model based on individual units
g. Interbasin transfers	• Not applicable
h. Third party social and economic impacts from voluntary redistribution of water	• Not applicable
i. Efficient use of existing water supplies and regional opportunities	• Very high
j. Effect on navigation	• none

4C.31 Growth Management as a Water Management Strategy

As is the case for practically all of the 16 water planning regions of Texas, the South Central Texas Region is projected to have significant population and economic growth during the 2000 to 2060 planning period. For example, population is projected to increase at a compound annual rate of 1.247 percent per year from 2,042,221 in year 2000 to 4,297,786 in 2060 and municipal water demands are projected to increase at a compound annual rate of 1.05 percent per year from 340,030 acft in year 2000 to 637,236 acft in 2060. Projected total water demands increase at a compound annual rate of 0.586 percent per year from 896,353 acft in year 2000 to 1,273,003 acft in 2060.

The population and the economy of the region both need water, with the quantity of water needed depending upon the technologies of municipal living, including commercial activities and services, industrial processes, and agricultural production. The projections that have been made of water demands to meet the projected population and economic growth are based upon trends of water use per unit population and water using industry that are embedded in the water use data that have been reported to the TWDB. For example, effects of low flow plumbing fixtures upon municipal per capita water use, and best management irrigation practices effects upon quantities of water applied per acre irrigated have affected the quantities of water used in these activities, and thereby have positioned the curves and the trends of water use, when viewed through time. Thus, the projections of the number of people who will reside within the region, and the kinds and types of industry, commercial activity, irrigation, and livestock, together with the quantity of water needed per unit population and economic activity determine the quantities of water that are projected to be needed.

In regional water planning, water management strategies are means and/or methods to meet projected water needs (shortages) of water user groups. Such water management strategies have been developed for inclusion in the 2006 Regional Water Plan, and include municipal and irrigation water conservation, as well as water supply projects, such as additional water wells to increase quantities available from aquifers, and additional surface water projects to increase quantities of water available from surface sources. In keeping with this concept of water management strategy, growth management as a water management strategy can perhaps function to allow population and other water using activities to occur within the region at projected rates, but with lower unit requirements of water than has been projected for regional water planning, as is explained below. Growth management is discussed below, however it is not possible to present estimates of quantities of water, environmental effects, costs, nor implementation issues as has been done for other water management strategies included in the plan, such as water conservation and groundwater and surface water projects.

Growth management, as a water management strategy to meet projected water needs (shortages) involves two major types of activities or procedures, as follows: (1) creation/adoption/use of housing and commercial structures and landscapes for the additional population that is projected for the region of a type(s) that requires less water than the type(s) underlying the projections, and (2) selection of businesses and industries that require/use less water per unit activity than underlies the projections for these water using components of the region. It is emphasized, that growth management is not directed at changing (reducing or increasing) the population and economic projections for which the region is planning. Growth management as a water management strategy is not a strategy to avoid the projected population and economic increases. Instead, growth management as a water management strategy is a set of policies and principals to guide and direct the development of housing and commercial structures into types that use less water per unit population, and to simultaneously guide and direct the location of employers that use less water than the trends that underlie the water demand projections for which the region is planning. For example, the growth management strategy could operate so that new housing subdivisions to accommodate projected population growth over for the period from 2010 to 2060 be designed to use a lower quantity of water per unit than was projected based upon water use data used in making the municipal water demand projections that are to be met via the regional water plan.

Among the factors that influence water use, and through which growth management might be expected to function as a water management strategy in the 2006 Regional Water Plan are the following:

4C.31.1 Housing

- Lot Size/Housing Density
- Landscaping (Types/species of lawn grasses, ornamentals, shade trees)
- Plumbing Fixtures
- Water using appliances

4C.31.2 Industry

- Manufacturing (assembly versus refining and smelting)
- Commercial
- Service
- Warehousing/Trades

4C.31.3 Agriculture

- Efficient irrigation application methods
  - Furrow Dikes
  - Contour farming/Terracing
  - Low energy precision application systems
- Choice of Crops
  - Grazing versus Cultivated Crops
  - Dryland versus Irrigated (crops, vegetables, orchards, and forages)
  - Irrigated Crops (Low water using, drought tolerant strains and varieties)
    - Field Crops versus Vegetables
    - Field Crops versus Orchards
    - Cotton versus Corn
    - Grain Sorghum versus Corn

The water management elements of each of the factors listed above is discussed below. In the case of housing and commercial establishments, growth management could be enlisted to reduce landscape water needs from municipal water systems, by reducing lot sizes, and selecting drought tolerant lawn grasses and landscape plants. In this case, the factors are similar to those of municipal water conservation, however they would be a part of “new” municipal ordinances applicable to new housing and commercial developments chosen for the purpose of reducing overall water needs, as opposed to retrofitting and modifying existing housing and commercial structures (e.g., build less water demanding housing, offices, and commercial structures for new population and business). Rainwater harvesting for water supply and gray water plumbing for landscape irrigation could be included in the design and construction of structures, as a part of the growth management initiative.

Housing — In the region, both single family and multiple family housing structures are in existence, and have been selected by the private sector subject to municipal and county zoning ordinances and/or density regulations. The resulting densities, landscaping choices, and practices have established a municipal water demand condition; i.e.; per capita water use datum that is similar among the cities of the region, but is somewhat unique among cities. The important point to be considered in terms of future water requirements is the selection of ordinances and regulations that will result in desirable living conditions for individuals and the community, in general, but will require less water per unit than the existing set of regulations and ordinances has established. For example, in growth management terms, modification of existing ordinances regarding platting of lot sizes to require that lots for new homes and apartments be only XX percent (XX to be determined by each jurisdiction via public process used in ordinance adoption by the jurisdiction) the size previously specified. Such modifications could reduce the quantity of water needed for lawn watering by YY percent (Again, the percentage to be determined as a part of the ordinance making process).

In the case of landscaping of new housing subdivisions and commercial complexes, it would be necessary for each jurisdiction to follow its respective ordinance making procedures, and through the public process reach decisions about goals and methods for use in adopting low water requiring landscape designs and plants. The possibilities reside with goals and objectives of the community, technical capabilities, public health and safety, and tastes and preferences of those involved.

In the case of plumbing fixtures for residential, commercial, institutional, public places, low-flow types were specified by both State and Federal law several years ago, and are therefore not expected to exhibit potential for further reductions in municipal water demands. However, in the case of water using appliances, such as clothes and dish washers, water-efficient types are available, and could be considered through ordinance making processes. State and Federal laws have not mandated that only the water-efficient types be manufactured and sold, as in the case of low-flow plumbing fixtures.

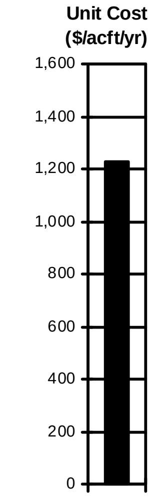
Industry — In the case of projected growth in the manufacturing and business services sectors that are expected to be attracted to the labor force and the markets of the projected growing population, the economic development organizations could focus upon recruiting and encouraging only low water using establishments to locate within the region; (e.g., do not recruit manufacturing concerns that require water in the production process, such as petroleum refining and metals smelting). It is important to note that heavy water using industries have located and may continue to be attracted to coastal areas of Region L, whereas the types of industries that have located in the interior areas of Region L have been the product assembly and personal services types that do not require significant quantities of water in the production processes. Thus, attention to these factors may not offer much promise for the interior areas of Region L, since these factors appear to have been and continue to be major considerations in business location decisions affecting growth and expansion within these parts of the Region L.

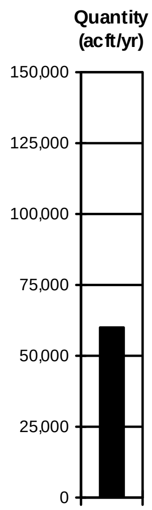
Agriculture — In Region L, both dryland and irrigated production methods are used. Irrigation using available groundwater and surface water locally is supplemental to precipitation in the western part of the region, and has developed over time in response to weather cycles (e.g., during settlement of the area, farming and ranching was undertaken based upon observed precipitation, but as time passed, and dry weather cycles appeared, farmers and ranchers turned to use of locally available water to save crops from failure due to lack of rain). There were not many readily available sources of flowing surface water, but the discovery and pumpage of water from large deposits of groundwater in the Edwards, Carrizo and Gulf Coast Aquifers lying beneath land which could be tilled proved to be economically feasible, and irrigated agriculture was developed extensively in Uvalde, Medina, Bexar, Zavala, Frio, and Atascosa Counties, and to a lesser extent in Dimmit, Wilson, and LaSalle Counties. Irrigated production included(s) vegetables, grains, cotton, forage, and orchard crops in these counties, while in Calhoun and Victoria Counties in the coastal areas, irrigation from both surface and ground sources was developed, with the main crop being rice.

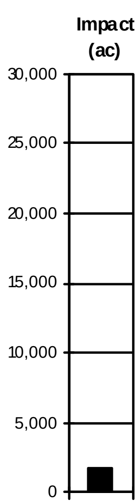
With respect to growth management in the existing agricultural sectors of the region, given that water supplies available are declining due to mining of supplies from the Carrizo Aquifer in the western counties of the region, declining water levels in local areas of the Gulf Coast Aquifer, and limits upon pumping from the Edwards Aquifer, management decisions should always be focused upon use of efficient cultivation and irrigation application techniques such as contour cultivation and furrow dikes to hold precipitation on the fields, low energy precision application of available irrigation water (See Section 4C.1.2 for description of efficient irrigation application methods). In addition, consideration could be given to shifting from traditional irrigated crops to others that require less water. For example, grow field crops, such as grains, which require 12 to 15 inches of water per acre, instead of vegetables that require 24 to 36 inches of water per acre. Or, in the case of grains, grow grain sorghum, which requires about 12 inches of supplemental water per acre to be successful, instead of corn which requires more than 40 inches per acre. However, suggesting that crop mixes be changed as a water management strategy must be carefully evaluated, since those in existence have been selected by farmers on the basis of technical and economic factors, personal expertise and preferences, and perhaps cultural and sociological considerations. Obviously, the choice of crops produced determines the profitability of farming and the level of farm income. Producing high value crops, such as vegetables and orchard crops, if successful, usually results in higher farm incomes per acre than does grains and cotton, and rice. Thus, the choice of crops to produce determines the level of living and welfare of the producer and the producer's families, and must be carefully considered. Nevertheless, if water is not available, and can not be made available in sufficient quantities at acceptable costs, as is the case in Region L, then some of the elements of efficiency and crop mix mentioned above may need to be considered within the context of growth management for the irrigation water user group of the region.

In summary and conclusion, it is reemphasized, that growth management would not be directed at changing (reducing or increasing) the population and economic projections for which the region is planning, nor would growth management be a strategy to avoid the projected population and economic increases. Instead, growth management, as a water management strategy, would be: (1) the development and adoption of policies and principals to guide and direct the development of housing and commercial structures into types that use less water per unit population, (2) encouragement of the location of industries to the region that use less water than the industries included in the trends that underlie the water demand projections for which the region is planning, and (3) guidance for large water using sectors, such as irrigated agriculture, to improve technical water use efficiencies, and consider shifting into other, less water demanding types of production.

2006 South Central Texas Regional Water Plan
Water Management Strategy Summary Sheet







Name: Lower Guadalupe Water Supply Project for Upstream GBRA Needs

Description: The project includes the diversion of underutilized surface water from the Guadalupe-Blanco River Authority (GBRA) Calhoun Canal System water rights to portions of Caldwell, Hays, Guadalupe, Comal, and Kendall Counties. Facilities include a 187 cfs canal intake and pump station; a 3-mile, 96-inch diameter diversion pipeline from the Canal System to a 19,000 acft off-channel reservoir in Calhoun County; a 160-mile transmission pipeline from the reservoir to the northwest delivery points, including a 60 inch, 112 mile transmission pipeline to Luling; a 54 inch, 27 mile transmission pipeline to Lake Dunlap; a 33 inch, 6 mile transmission pipeline to New Braunfels; and a 20 inch, 15 mile transmission pipeline to Western Canyon Project. The SCTRWPG has developed the following statement with regard to the LGWSP for Upstream GBRA Needs and environmental flows:

> "*As part of the development and implementation of the Lower Guadalupe Water Supply Project for Upstream GBRA needs, the Guadalupe-Blanco River Authority recognizes and supports the need to address inflow amounts necessary to protect and preserve a healthy ecosystem in the San Antonio Bay - Guadalupe Estuary system in conjunction with the development of water supplies to meet human water needs. The specifics of the inflow requirements will be determined through the state-mandated Senate Bill 3 environmental flows process which is intended to 1) determine the water needs of the environment based on science and other factors such as future changes in projected human needs, 2) reserve from new surface water appropriation, water needed for the environment as established in the environmental flows process and 3) encourage voluntary efforts to provide water for the environment from existing water rights.*
>
> *The Guadalupe-Blanco River Authority will work with Region L participants and other public and private water rights holders in the basin toward the development of a voluntary strategy to promote environmental stewardship and provide for the prudent management of the water and environmental resources of the San Antonio and Guadalupe Rivers and the San Antonio Bay-Guadalupe Estuary system within the framework of existing and future surface water rights, as well as existing and future alternative sources of supply. Any effort to develop a voluntary strategy will recognize and work in concert with the environmental flows process set out in Senate Bill 3."*

***Decade Needed*:** 2010 – 2020

Cost, Quantity of Water, and Land Impacted

Unit Cost of Water (2Q 2002):	**$1,226**	**$/acft/yr**	**Treated Water Delivered**
Unit Cost of Water (2Q 2007):	**$1,506**	**$/acft/yr**	
Quantity of Water:	**60,000**	**acft/yr**	**Reliability = Firm**
Land Impacted:	**1,817**	**acres**	

Lower Guadalupe Water Supply Project for Upstream GBRA Needs (cont'd)

Additional Considerations per Regional Water Planning Guidelines

Environmental Factors:

In Calhoun, Victoria, De Witt, Guadalupe, Gonzales, Caldwell, and Comal Counties, 41 state-listed endangered or threatened species and 22 federally-listed endangered or threatened wildlife species, may occur according to the county lists of rare species published by Texas Parks and Wildlife Department (TPWD). The threatened Cagle's map turtle, the endangered fountain darter fish, and the endangered Comal Springs dryopid beetle have all been sited within a one mile radius of the pipeline area. The wintering population of the endangered Whooping Crane at the Aransas National Wildlife Refuge is located adjacent to the lower San Antonio Bay. Endangered and threatened species listed for Comal County include the Black-capped Vireo, Golden-cheeked Warbler, and four additional migratory bird species, two salamanders, an amphipod, and two beetles.

Impacts on Water Resources:

Some reductions in freshwater inflows to the Guadalupe Estuary associated with greater utilization of existing water rights.

Impacts on Agricultural & Natural Resources:

Minimal, if any.

Other Relevant Factors per SCTRWPG:

Project developed by SCTRWPG in association with GBRA (HB3776).

Project includes facilities for diversion of up to 75,000 acre-feet per year (below the City of Victoria) and transmission, treatment, and delivery of up to 60,000 acre-feet per year of surface water, provided however that at least 100,000 acre-feet per year of surface water must be reserved for lower basin needs (HB3776).

Project includes no use of fresh groundwater (HB3776).

Consent of affected property owners must be obtained before an off-channel reservoir may be developed as part of the project (HB3776).

GBRA and SCTRWPG have adopted language that recognizes and supports the need to address inflow amounts necessary to protect and preserve a healthy ecosystem in the San Antonio Bay - Guadalupe Estuary system in conjunction with the development of water supplies to meet human water needs (HB3776).

Project encourages beneficial use of available rights.

Project maintains instream flows and recreational opportunities throughout the basin through lower basin diversion.

Comparison of Strategies to Meet Needs:

No conflicts with other recommended water management strategies.

Interbasin Transfer Issues:

Since this specific strategy is intended to serve water user groups within the GBRA district, no inter-basin transfer issues are anticipated.

Third-Party Impacts of Voluntary Transfers:

None anticipated.

Regional Efficiency:

None.

Water Quality Considerations:

The off-channel reservoir will aid in suspending river diversions to avoid poor water quality during flood events and facilitate maintenance of diversion facilities without stopping reservoir deliveries.

4C.33 Lower Guadalupe Water Supply Project (LGWSP) for Upstream GBRA Needs

4C.33.1 Description of Water Management Strategy

The Lower Guadalupe Water Supply Project (LGWSP) for Upstream GBRA Needs water management strategy presented herein involves the diversion of up to 75,000 acft/yr of presently underutilized surface water rights from the Guadalupe-Blanco River Authority (GBRA) Calhoun Canal System. The project includes a 3-mile diversion pipeline from the Canal System to an off-channel reservoir, from which transmission pipeline segments totaling 160 miles in length would deliver raw water to treatment plants at Luling, Lake Dunlap and/or San Marcos, New Braunfels, and the Western Canyon Project (Figure 4C.33-1). Treated water is then integrated into the municipal water supply systems of present and future GBRA customers. To the extent that supplies in excess of those being used by GBRA's municipal customers are available, water supplies associated with this strategy may also be used to meet projected needs of GBRA's non-municipal customers. Such uses are deemed consistent with the 2006 SCTRWP if any necessary supplemental authorizations are obtained pursuant to Texas Commission on Environmental Quality (TCEQ) rules and applicable law.

The GBRA lower basin water rights total 175,501 acft/yr and represent about 30 percent of all surface water rights in the Guadalupe-San Antonio River Basin authorized for consumptive use. A majority of these rights are jointly held with the Dow Chemical Company/Union Carbide Corporation. These GBRA water rights are quite reliable, as the upstream watershed encompasses approximately 10,128 square miles and includes the two largest springs in Texas. In addition, substantial volumes of treated effluent are discharged upstream of the proposed diversion point. In all years, there is unappropriated streamflow passing the Guadalupe River Saltwater Barrier and entering the Guadalupe Estuary. However, junior portions of the GBRA rights committed to the LGWSP may not be "firm" (i.e., 100 percent reliable) during each month of a repeat of the most severe drought on record. Hence, this strategy includes off-channel storage facilities that serve to "firm-up" (increase the reliability of) run-of-river diversions to be used for municipal and industrial purposes.

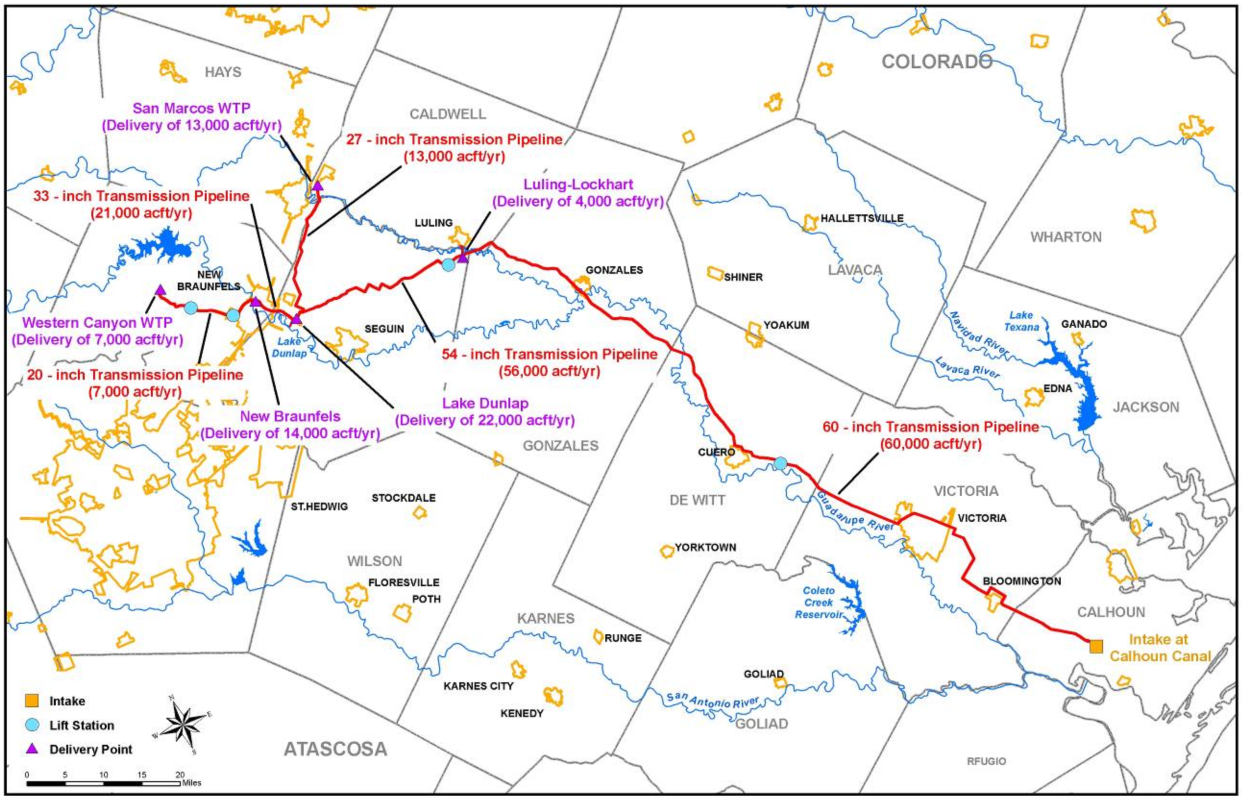


Figure 4C.33-1. LGWSP for Upstream GBRA Needs — Location Map

The water management strategy presented herein differs from the one presented in the 2006 South Central Texas Regional Water Plan (SCTRWP) adopted January 19, 2006 in that it was formulated in response to legislation set forth in HB 3776 of the 80th Texas Legislature. A sub-section of HB 3776 includes provisions for approving the 2006 SCTRWP so long as the LGWSP for Upstream GBRA Needs water management strategy is revised to include the following conditions:

1. Include a transmission pipeline for the diversion of up to 60,000 acre-feet per year of surface water available under water rights held by the Guadalupe-Blanco River Authority as of December 31, 2006;
2. At least 100,000 acre-feet per year of surface water must be reserved for lower basin needs;
3. Prohibit use of fresh groundwater for the project;
4. Require the consent of appropriate property owner(s) before off-channel storage or an off-channel reservoir may be developed as part of the project; and

5. Require freshwater inflows in an amount sufficient to meet the Texas Parks and Wildlife Department, Texas Commission on Environmental Quality, and Texas Water Development Board's environmental consensus criteria for San Antonio Bay to be identified and included in the project.

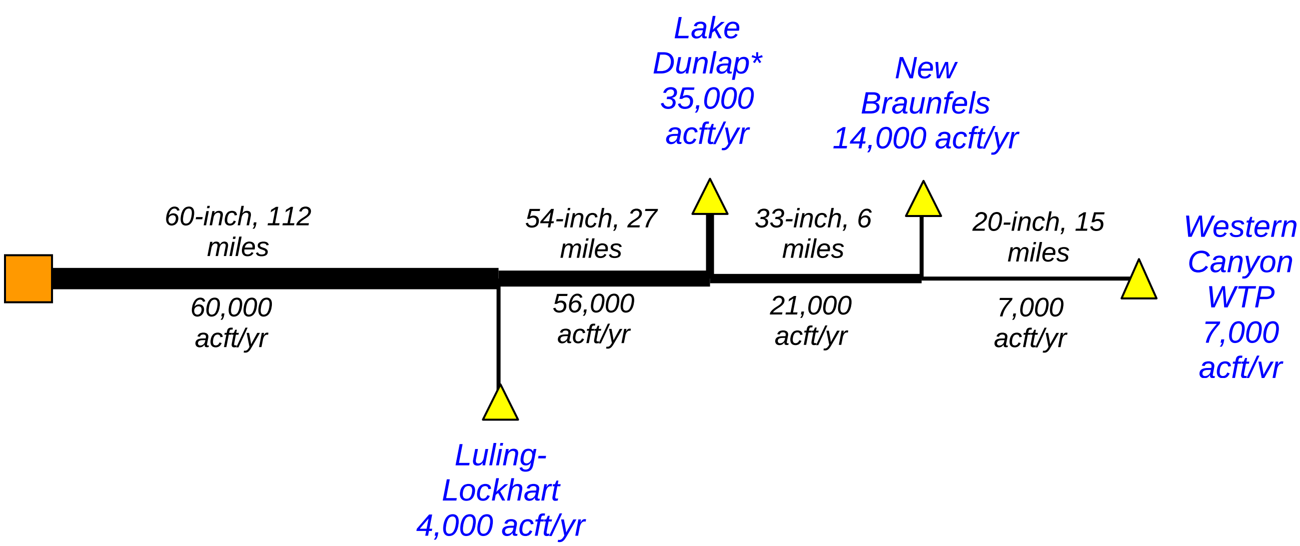
Interpretation of the language in HB 3776 has been debated, as the bill references only the 2006 SCTRWP, and not any future Regional Water Plans. The South Central Texas Regional Water Planning Group (SCTRWPG) has evaluated the LGWSP for Upstream GBRA Needs to ensure that long-term, reliable, and renewable surface water supplies will be available throughout the GBRA statutory district. Furthermore, the SCTRWPG has developed the following statement with regard to the LGWSP for Upstream GBRA Needs and environmental flows:

> *As part of the development and implementation of the Lower Guadalupe Water Supply Project for Upstream GBRA needs, the Guadalupe-Blanco River Authority recognizes and supports the need to address inflow amounts necessary to protect and preserve a healthy ecosystem in the San Antonio Bay - Guadalupe Estuary system in conjunction with the development of water supplies to meet human water needs. The specifics of the inflow requirements will be determined through the state-mandated Senate Bill 3 environmental flows process which is intended to 1) determine the water needs of the environment based on science and other factors such as future changes in projected human needs, 2) reserve from new surface water appropriation, water needed for the environment as established in the environmental flows process and 3) encourage voluntary efforts to provide water for the environment from existing water rights.*
>
> *The Guadalupe-Blanco River Authority will work with Region L participants and other public and private water rights holders in the basin toward the development of a voluntary strategy to promote environmental stewardship and provide for the prudent management of the water and environmental resources of the San Antonio and Guadalupe Rivers and the San Antonio Bay-Guadalupe Estuary system within the framework of existing and future surface water rights, as well as existing and future alternative sources of supply. Any effort to develop a voluntary strategy will recognize and work in concert with the environmental flows process set out in Senate Bill 3.*

The LGWSP for Upstream GBRA Needs, as defined by the SCTRWPG, is described below:

1. Modeling Assumptions:
   a. Diversion of up to 75,000 acft/yr under GBRA water rights per the Certificates of Adjudication.
   b. Edwards Aquifer pumpage consistent with SB3 (80th Texas Legislature).
   c. Off-channel storage as necessary.
   d. No use of fresh groundwater supplies.
   e. Delivery amount of 60,000 acft/yr.

2. Cost Estimate Assumptions:
   a. Diversion pump station at existing GBRA Relift #1 Pump Station site on Calhoun Canal System.
   b. Off-channel storage in Lower Basin.
   c. Transmission through GBRA District and delivery to Luling, Lake Dunlap, New Braunfels, and the Western Canyon Project in the amounts shown Figure 4C.33-1.
   d. Treatment and integration facilities.



** Approximately 13,000 acft/yr is needed for the IH35 Corridor (Including San Marcos)*

Figure 4C.33-2. LGWSP for Upstream GBRA Needs — Schematic of Delivery Amounts

Inclusion of off-channel storage has certain operational advantages in addition to increasing firm water availability. These advantages include the capability of suspending river diversions to avoid poor water quality during flood events and/or facilitate maintenance of diversion facilities without curtailing deliveries from the reservoir. Off-channel storage will not be developed as part of this project without the consent of affected property owners.

4C.33.2 Water Availability

The Guadalupe River Saltwater Barrier was constructed in the early 1960s at a location immediately downstream of the San Antonio River confluence and creates a reservoir pool extending some distance up both rivers. Diversions from this reservoir pool, under existing rights, flow into GBRA's Calhoun Canal System and are dependent upon waters originating in both the Guadalupe and San Antonio Rivers and their respective tributaries. Since the end users of the LGWSP for Upstream GBRA Needs are customers within the 10-county GBRA statutory district and part of each of the 10 counties is with in the Guadalupe River Basin, this version of the LGWSP is not subject to many provisions of Section 11.085 of the Texas Water Code regarding inter-basin transfers.

Maximum reported water use under the GBRA lower basin water rights totaling 175,501 acft/yr at the Guadalupe River Saltwater Barrier did not exceed 63,000 acft/yr during the 1991 through 2006 historical period[1]. It is estimated by GBRA that up to 75,000 acft/yr under one or more of these rights is available for periods of time into the future leaving 100,000 acft/yr available for lower basin uses. Certificate of Adjudication (CA) #18-5178 is the least senior of GBRA's lower basin water rights and it has a priority date of January 7, 1952. Authorized annual diversions under CA# 18-5178 total 106,000 acft for municipal, industrial, and irrigation uses.

The Guadalupe-San Antonio River Basin Water Availability Model (GSAWAM, as modified for regional water planning purposes) was used to quantify water available for diversion under CA# 18-5178. Hydrologic simulations and calculations were performed subject to the General Assumptions for Applications of Hydrologic Models, as adopted by the SCTRWPG for the 2006 Regional Water Plan, with a modification to include the latest Edwards Aquifer permitted pumping capacity and Critical Period provisions as set forth in SB3. A maximum diversion rate of 187 cfs (the pro-rata share of the maximum diversion rate in CA# 18-5178 or [264.35 cfs * 75,000 acft / 106,000 acft] = 187.0 cfs) was used. A specifically-designed MS Excel model was then used to simulate off-channel storage operations, while meeting the

[1] GBRA, Personal Communication, 2007.

60,000 acft/yr delivery to GBRA customers. Results obtained using both the GSAWAM and the Excel model to evaluate the project are presented in the following paragraphs.

Application of the GSAWAM, with a period of record from January 1934 to December 1989, demonstrates that water availability from the Guadalupe River, via the Calhoun Canal System, is very reliable. Figure 4C.33-3 shows the water available for diversion under the junior 75,000 acft/yr portion of CA# 18-5178 on an annual basis, limited only by a maximum diversion rate of 187 cfs. Actual diversions from the Guadalupe River to the off-channel reservoir are further limited by amounts necessary to keep the reservoir full. Subject to a uniform seasonal diversion pattern, the full monthly portion of 75,000 acft/yr is available in about 96 percent of the months simulated. Water available from the Calhoun Canal System was used in the Excel model to maintain storage in the off-channel storage facility sized to meet the specified 60,000 acft/yr delivery requirement.

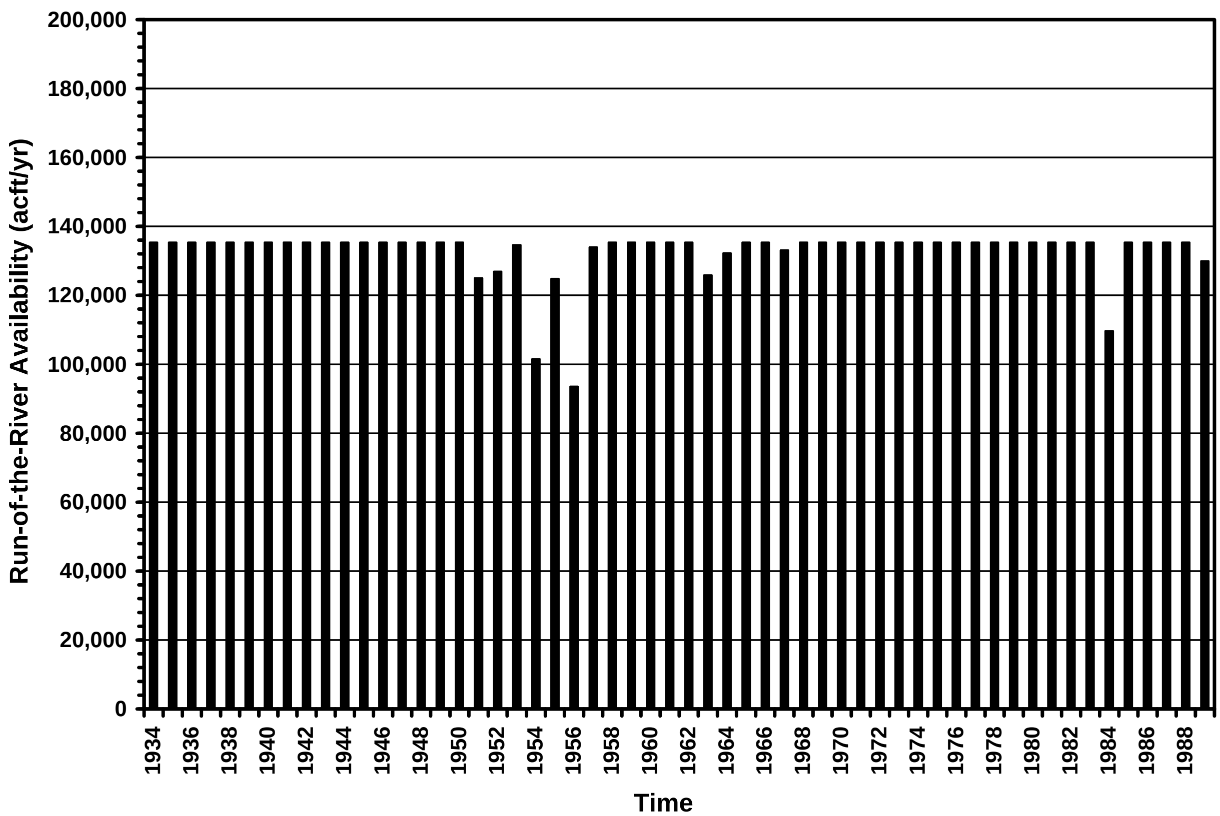


Figure 4C.33-3. Availability from Guadalupe River under Junior Portion of CA# 18-5178, Limited by Maximum Diversion Rate of 187 cfs

During relatively short periods during the 1934 – 1989 period of record, water is not available under CA# 18-5178, and diversions must be made from storage. It is assumed that the off-channel storage facility would be located in Calhoun County. Through an iterative process in the Excel model, it was determined that the storage necessary to sustain uniform delivery of 60,000 acft/yr is approximately 19,000 acft, based on a ring dike type structure limited to about 20-feet deep. An off-channel storage reservoir of this size would inundate approximately 950 acres. The long-term average net evaporative loss associated with a reservoir of this size in the lower Guadalupe River Basin is expected to be 2,160 acft/yr (3.6 percent of firm yield). The maximum annual diversion under CA# 18-5178 is 64,198 acft/yr in this project.

It is noted that GBRA could provide most, if not all, of the 60,000 acft/yr delivery amount using CA# 18-5176, CA# 18-5177, and/or more senior portions of CA# 18-5178, rather than the junior portion of CA# 18-5178. This would substantially reduce off-channel storage requirements, but could necessitate occasional suspension of water use for irrigation.

4C.33.3 Environmental Issues

The LGWSP for Upstream GBRA Needs includes a 3-mile diversion pipeline from the GBRA Calhoun Canal System to an off-channel storage facility in Calhoun County and a 160-mile long transmission pipeline from the off-channel storage facility to delivery points in the middle and upper Guadalupe River Basin. The transmission pipeline originates in Calhoun County and runs in a northwesterly direction through portions of Calhoun, Victoria, De Witt, Gonzales, Caldwell, Guadalupe, and Comal Counties.

A construction right-of-way approximately 140-feet wide would affect a total area of approximately 2,700 acres. The construction of the pipelines would include the clearing and removal of woody vegetation within and maintenance of a 40-foot wide right-of-way free of woody vegetation for the life of the project (1,943 acres of temporarily disturbed construction corridor).

The project area is located primarily in the Gulf Coastal Plains of Texas Physiographic Province. This area is locally characterized as a nearly flat prairie which terminates at the Gulf of Mexico, and includes topography changes of less than one foot per mile. Elevation levels in this area range from 0 to 300 feet above mean sea level. Vegetation types found within the pipeline corridor are primarily live oak and post oak woodlands, with crops as the second largest type and the remaining portions containing grasslands and urban areas.

The pipeline route encompasses four different vegetational areas, The Gulf Prairies and Marshes, Post Oak Savannah, Blackland Prairies, and Edwards Plateau. The portion of the pipeline route found within Calhoun County and the majority of Victoria County crosses the Gulf Prairies and Marshes Vegetational Area. Gulf Prairies have slow surface drainage and elevations that range from sea level to 250 feet. These areas include nearly level and virtually undissected plains. Originally the Gulf Prairies were composed of tallgrass prairie and post oak savannah. However, tree species such as honey mesquite and acacia, along with other trees and shrubs, have increased in this area, forming dense thickets in many places.

Typical oak species found in this area include live oak (Quercus virginiana) and post oak (Q. stellata), in addition to huisache (Acacia smallii), black-brush (A. rigidula), and a dwarf shrub, bushy sea-ox-eye (Borrichia frutescens). Principal climax grasses of the Gulf Prairies include gulf cordgrass (Spartina spartinae), indiangrass (Sorghastrum nutans), and big bluestem (Andropogon gerardii var. gerardii). Prickleypear (Opunita) are common within this area along with forbs including asters (Aster), poppy mallows (Callirhoe), bluebonnets (Lupinus), and evening primroses (Oenothera). Gulf Marshes range from sea level to a few feet in elevation, and include low, wet marshy coast areas commonly covered with saline water. These salty areas support numerous species of sedges (Carex and Cyperus), bulrushes (Scirpus), rushes (Juncus), and grasses. Aquatic forbs found in these areas generally include pepperweeds (Lepidium), smartweeds (Polygonum), cattails (Typha domingensis) and spiderworts (Tradescantia) among others. Upland game and waterfowl find these low marshy areas to be excellent natural wildlife habitat.

The Post Oak Savannah vegetational area of Texas includes portions of De Witt, Guadalupe, Gonzales, and Caldwell counties. The Post Oak Savannah refers to the gently rolling, moderately dissected, wooded plain that lies to the west of the Pineywoods in east-central Texas and intermingles with the Blackland Prairie in south-central Texas. The elevation in this area ranges from 300-800 feet. This vegetation area includes the entire Claypan land resource area of Texas, which is considered part of the Southern Coastal Plains. Vegetation is typified by post oak (Quercus stellata) and blackjack oak (Quercus marilandica) in association with tallgrasses. Dense thickets may occur within this area in the absence of fire or other methods of woody plant suppression. The Post Oak Savannah was extensively cultivated until the 1940's, but numerous acres have since been restored to native vegetation or converted to tame pastures.

In addition to post oak and blackjack oak, associated trees of the Post Oak Savannah include elms (Ulmus spp.), junipers (Juniperus spp.), hackberries (Celtis spp.), and hickories (Carya spp.). Understory vegetation includes shrubs such as yaupon (Ilex vomitoria), American beautyberry (Callicarpa americana), coralberry (Symphoricarpos orbiculatus), and vines such as greenbriars (Smilax spp.) and grapes (Vitis spp.). Common climax grasses include little bluestem (Schizachyrium scoparium), indiangrass (Sorghastrum nutans), switchgrass (Panicum virgatum), silver bluestem (Bothriochloa laguroides), Texas wintergrass (Nassella leucotricha), brownseed paspalum (Paspalum plicatulum) purpletop (Tridens flavus), narrow leaf woodoats (Chasmanthium laxum), and beaked panicum (Panicum anceps). Forbs occurring in the area include wild indigos (Baptisia spp.), indigobush (Amorpha fruticosa), sennas (Senna spp.), tickclovers (Desmodium spp.), lespedezas (Lespedeza spp.), prairie clovers (Dalea spp.), western ragweed (Ambrosia psilostachya), crotons (Croton spp.), and sneezeweeds (Helenium spp.).

The Blackland Prairies refers to rolling hills of well-dissected prairie in west-central Texas and represents the southern extension of the true prairie that occurs from Texas to Canada. Portions of this type of vegetational area are included in De Witt, Guadalupe, Gonzales, Comal, and Caldwell counties. The region was once a tallgrass prairie dominated by little bluestem (Schizachyrium scoparium), big bluestem (Andropogon gerardii), indiangrass (Sorghastrum nutans), tall dropseed (Sporobolus compositus), and Silver dropseed (Sporobolus silveanus). Oaks (Quercus spp.), elms (Ulmus spp.), cottonwood (Populus deltoides), and native pecan (Carya illinoinensis) are common along streams in this region. About 98 percent of the Blackland Prairies were cultivated to produce crops such as cotton, corn, and wheat in the late 19th and early 20th centuries. Since the 1950’s, the region has been increasingly used for pasture and forage crops for the production of livestock, and now only about 50 percent of the area is used as cropland.

The Edwards Plateau vegetational area occurs within the western portions of Comal and Hays counties. This area includes rapidly drained stony plains with broad flat divides. The original vegetation within this area was grassland or open savannah-type plains with most tree or brushy species found along rocky slopes and stream bottoms. The Edwards plateau is currently primarily rangeland with short grasses. Along rocky outcrops and protected areas with good soil moisture you will still find tallgrasses such as cane bluestem (Bothriochloa barbinodis var. barbinodis), indiangrass (Sorghastrum nutans), and switchgrass (Panicum spp.) Common woody species include live oak (Quercus virginiana), sand shin oak (Quercus havardii), mesquite (Prosopis glandulosa) and ashe juniper (Juniperus ashei).

In Calhoun, Victoria, De Witt, Guadalupe, Gonzales, Caldwell, and Comal Counties, 41 state-listed endangered or threatened species and 22 federally-listed endangered or threatened wildlife species, may occur according to the county lists of rare species published by Texas Parks and Wildlife Department (TPWD). A list of these species is provided in Table 4C.33-1.

Inclusion in Table 4C.33-1 does not imply that a species will occur within the study area, but only acknowledges the potential for occurrence in the study area counties. A more intensive field reconnaissance would be necessary to confirm and identify specific suitable habitat that may be present in the project area. In addition to county lists, HDR also reviewed Texas Natural Diversity Database (TXNDD) map data for known occurrences of listed species within or near the proposed pipeline route. This information indicated that there were reported sightings of Cagle's map turtle (Graptemys caglei), a state listed threatened species; the fountain darter fish (Etheostoma fonticola), listed by both the state and federal government as endangered; the Comal Springs dryopid beetle (Stygoparnus comalensis), which is federally listed as endangered; within a one mile radius of the pipeline area. Two rare species are also documented, the Guadalupe bass (Micropterus teculii) and the mountain plover (Charadrius montanus). The presence or absence of potential habitat within an area does not confirm the presence or absence of a listed species. No species specific surveys were conducted in the study area for this report.

Table 4C.33-1
Important Species Having Habitat or Known to Occur in
Calhoun, Caldwell, Comal, DeWitt, Gonzales, Guadalupe, and Victoria Counties

Common Name	Scientific Name	Summary of Habitat Preference	Listing Entity USFWS[1]	Listing Entity TPWD[1]	Potential Occurrence in Counties
A mayfly	Campsurus decoloratus	TX and MX; possibly clay substrates;			Resident
A mayfly	Tortopus circumfluus	Generally found in shoreline vegetation			Resident
American Eel	*Anguilla rostrata*	Moist aquatic habitats			Resident
Atlantic Hawksbill Sea turtle	*Eretmochelys imbricata*	Gulf and bay systems	LE	E	Migrant
Attwater's Greater Prairie-chicken	*Tympanuchus cupido attwateri*	Endemic, open prairies and coastal plains	LE	E	Resident
Bald Eagle	*Haliaeetus leucocephalus*	Large bodies of water with nearby resting sites	DL	T	Nesting/ Migrant

Table 4C.33-1 (Continued)

Common Name	***Scientific Name***	***Summary of Habitat Preference***	***Listing Entity***		***Potential Occurrence in Counties***
			USFWS[1]	***TPWD[1]***	
Big red sage	*Salvia penstemonoides*	Endemic; moist to seasonally wet clay or silt soils in creek beds.			Resident
Black Bear	*Usus americanus*	Mountains, broken country, woods, brushlands, forests	T/SA; NL	T	Historic Resident
Black-capped Vireo	Vireo atricapillus	Semi-open broad-leaved shrublands	LE	E	Nesting/ Migrant
Black-Spotted Newt	*Notophthalmus meridionalis*	Ponds and resacas in south Texas		T	Resident
Blue sucker	Cycleptus elongatus	Larger portions of major rivers in Texas;		T	Resident
Bracted Twistflower	*Streptanthus bracteatus*	Endemic; Shallow clay soils over limestone; rocky slopes			Resident
Brown Pelican	*Pelecanus occidentalis*	Coastal inlands for nesting, shallow gulf and bays for foraging	LE	E	Nesting/ Migrant
Canyon mock-orange	*Philadelphus ernestii*	Endemic, outcrops of limestone			Resident
Cagle's map turtle	*Graptemys caglei*	Endemic; Guadalupe River System		T	Resident
Cascade Caverns salamander	*Eurycea latitans complex*	Endemic: subaquatic, springs and caves in Medina and Guadalupe River and Cibolo Creek Watersheds		T	Resident
Cave myotis bat	*Myotis velifer*	Colonial and cave-dwelling;			Resident
Comal Blind Salamander	*Eurycea tridentifera*	Endemic; Semi-troglobitic; Springs and waters of caves		T	Resident
Comal snakewood	*Colubria stricta*	Rock outcrops			Resident
Comal Springs diving beetle	*Comaldessus stygius*	Aquatic, at outflow at Comal Springs			Resident
Comal Springs dryopid beetle	*Stygoparnus comalensis*	Aquatic, cling to objects in streams	LE		Resident
Comal Springs riffle beetle	*Heterelmis comalensis*	Comal and San Marcos Springs	LE		Resident
Comal Springs salamander	*Eurycea* sp. 8	Endemic; Comal Springs			Resident
Creeper (squawfoot)	*Strophitus undulates*	Small to large streams			Resident
Edwards Aquifer diving beetle	*Haideoporus texanus*	Artesian well in Hays County			Resident
Edwards Plateau Spring Salamander	*Eurycea sp. 7*	Endemic; springs and waters of caves within region			Resident

Table 4C.33-1(Continued)

Common Name	Scientific Name	Summary of Habitat Preference	Listing Entity		Potential Occurrence in Counties
			USFWS[1]	TPWD[1]	
Elmendorf's onion	*Allium elmendorfii*	Endemic, in deep sands			Resident
Eskimo curlew	*Numenius borealis*	Historic; grasslands, pastures	LE	E	Nonbreeding Historic Resident
Ezell's cave amphipod	*Stygobromus flagellatus*	Known from artesian wells			Resident
False spike mussel	*Quincuncina mitchelli*	Substrates of cobble and mud with water lilies present. Rio Grande, Brazos, Colorado and Guadalupe river basins.			Resident
Fountain darter	Etheostoma fonticola	Sam Marcos and Comal Rivers	LE	E	Resident
Golden-Cheeked Warbler	Dendroica chrysoparia	Woodlands with oaks and old juniper	LE	E	Nesting/ Migrant
Golden orb	*Quadrula aurea*	Sand and gravel, Guadalupe, San Antonio, and Nueces river basins			Resident
Green Sea Turtle	*Chelonia mydas*	Gulf and bay system.	LT	T	Migrant
Guadalupe bass	Micropterus treculii	Endemic to perennial streams of the Edward's Plateau region			Resident
Guadalupe darter	Percina sciera apristis	Guadalupe River basin; large streams and rivers			Resident
Gulf Saltmarsh Snake	Nerodia clarkii	Brackish to saline coastal waters			Resident
Henslow's Sparrow	*Ammodramus henslowii*	Weedy fields, cut over areas.			Nesting/ Migrant
Hill County wild-mercury	*Argythamnia aphoroides*	Shallow clays and limestone			Resident
Horseshoe liptooth snail	*Daedalochila hippocrepis*	Snal known only from Landa Park in New Braunfels			Resident
Jaguarundi	*Herpailurus yaguarondi*	South Texas thick brushlands, favors areas near water	LE	E	Resident
Kemp's Ridley Sea Turtle	*Lepidochelys kempii*	Gulf and bay system.	LE	E	Migrant
Leonora's dancer damselfly	Argia leonorae	South central and western Texas; small streams and seepages			Resident
Leatherback Sea Turtle	*Dermochelys coriacea*	Gulf and bay system.	LE	E	Migrant
Loggerhead Sea Turtle	*Caretta caretta*	Gulf and bay system.	LT	T	Migrant

Table 4C.33-1 (Continued)

Common Name	Scientific Name	Summary of Habitat Preference	Listing Entity		Potential Occurrence in Counties
			USFWS[1]	TPWD[1]	
Long-legged cave amphipod	*Stygobromus longipes*	Subaquatic obligate			Resident
Louisiana Black Bear	*Ursus americanus luteolus*	Within historical range.	LT	T	Historic Resident
Mountain Plover	*Charadrius montanus*	Non-breeding-shortgrass plains and fields, plowed fields and sandy deserts			Nesting/ Migrant
Ocelot	*Leopardus pardalis*	Dense chaparral thickets; mesquite-thorn scrub and live oak mottes	LE	E	Resident
Opossum Pipefish	*Microphis brachyurus*	Brooding adults found in fresh or low salinity waters.		T	Resident
Palmetto pill snail	Euchemotrema leai cheatumi	One known population, from moist palmetto woodlands of Palmetto State Park;			Resident
Park's jointweed	*Polygonella parksii*	Endemic; deep loose sands of Carrizo and similar Eocene formations.			Resident
Peck's cave amphipod	*Stygobromus pecki*	Aquatic crustacean, Comal Springs and Hueco Springs	LE	E	Resident
Peregrine falcon	*Falco peregrinus anatum (American)*	Open county; cliffs	DL	E	Nesting/ Migrant
	Falco peregrinus tundrius (Arctic)		DL	T	
Pistolgrip	*Tritogonia verrucosa*	Aquatic, stable substrate			Resident
Plains Spotted Skunk	*Spilogale putorius interrupta*	Prefers wooded, brushy areas and tallgrass prairie.			Resident
Rawson's metalmark	*Calephelis rawsoni*	Moist areas in limestone outcrops.			Resident
Red Wolf	*Canis rufus*	Extirpated	LE	E	Historic Resident
Reddish Egret	Egretta rufescens	Coastal inlands for nesting, coastal marshes for foraging		T	Migrant
Rock pocketbook	*Arcidens confragosus*	Mud and sand, Red through Guadalupe river basins			Resident

Table 4C.33-1 (Continued)

Common Name	Scientific Name	Summary of Habitat Preference	Listing Entity		Potential Occurrence in Counties
			USFWS[1]	TPWD[1]	
Sandhill woolywhite	*Hymenopappus carrizoanus*	Endemic; open areas in deep sands derived from Carrizo and similar Eocene formations			Resident
Sheep Frog	*Hypopachus variolosus*	Deep sandy soils of Southeast Texas		T	Resident
Shinner's sunflower	Helianthus occidentalis ssp plantagineus	Mostly in prairies on the Coastal Plain			Resident
Snowy Plover	*Charadrius alexandrinus*	Wintering Migrant on mud flats			Migrant
Sooty Tern	*Sterna fuscata*	Catches small fish		T	Resident
Southeastern Snowy Plover	*Charadrius alexandrinus tenuirostris*	Texas Gulf Coast beaches and bayside mud or salt flats			Wintering Migrant
Spot-tailed earless lizard	*Holbrookia lacerata*	Moderately open prairie-brushland			Resident
Texas asaphomyian tabanid fly	Asaphomyia texensis	Adults of tabanid spp. found near slow-moving water			Resident
Texas Diamondback Terrapin	*Malaclemys terrapin littoralis*	Bays, coastal marshes of the upper two-thirds of Texas Coast			Resident
Texas fatmucket	*Lampsilis bracteata*	Streams and rivers on sand, mud and gravel, Colorado and Guadalupe River basins			Resident
Texas Garter Snake	*Thamnophis sirtalis annectens*	Wet or moist microhabitats			Resident
Texas Horned Lizard	*Phrynosoma cornutum*	Varied, sparsely vegetated uplands, grass, cactus, brush		T	Resident
Texas mock-orange	*Philadelphus texensis*	Endemic, limestone cliffs and boulders			Resident
Texas pimpleback	*Quadrula petrina*	Mud, gravel and sand substrates, Colorado and Guadalupe river basins			Resident
Texas Scarlet Snake	*Cemophora coccinea lineri*	Mixed hardwood scrub		T	Resident
Texas Tortoise	*Gopherus berlandieri*	Open brush w/ grass understory; open grass/bare ground avoided		T	Resident
Timber/Canebrake Rattlesnake	*Crotalus horridus*	Floodplains, upland pine, deciduous woodlands, riparian zones		T	Resident

Table 4C.33-1 (Concluded)

Common Name	Scientific Name	Summary of Habitat Preference	Listing Entity		Potential Occurrence in Counties
			USFWS[1]	TPWD[1]	
Welder machaeranthera	*Psilactis heterocarpa*	Endemic, grasslands and adjacent scrub flats on clay			Resident
West Indian manatee	*Trichechus manatus*	Aquatic	LE	E	Resident
Timber/Canebrake Rattlesnake	*Crotalus horridus*	Floodplains, upland pine, deciduous woodlands, riparian zones		T	Resident
Western Burrowing Owl	*Athene cunicularia hypugaea*	Open grasslands, especially prairie, plains and savanna			Resident
Western Snowy Plover	*Charadrius alexandrinus nivosus*	Winters along coast			Migrant
White-faced Ibis	*Plegadis chihi*	Prefers freshwater marshes		T	Resident
White-nosed coati	*Nasua narica*	Woodlands, riparian corridors		T	Transient
White-tailed Hawk	*Buteo albicaudatus*	Coastal prairies, savannahs and marshes in Gulf coastal plain		T	Nesting/ Migrant
Whooping Crane	*Grus americana*	Potential migrant	LE	E	Migrant
Wood Stork	*Mycteria americana*	Forages in prairie ponds, ditches, and shallow standing water formerly nested in TX		T	Migrant
Zone-tailed Hawk	*Buteo albonotatus*	Arid open county near watercourse		T	Nesting/ Migrant

- LE/LT=Federally Listed Endangered/Threatened
- E/SA, T/SA=Federally Listed Endangered/Threatened by Similarity of Appearance
- DL, PDL=Federally Delisted/Proposed for Delisting
- E, T=State Listed Endangered/Threatened
- Blank = Rare, but no regulatory listing status

Source: TPWD, Annotated County List of Rare Species, Calhoun County, August 14, 2007, Victoria County November 20, 2007, De Witt County, November 20, 2007, Gonzales County August 8, 2007, Guadalupe County, August 8, 2007, and Caldwell County, November 20, 2007.

Many migratory birds are dependent on estuarine environments like those located near Calhoun County in order to complete their foraging and nesting requirements during migration. One of the most well known of these migratory birds is the whooping crane (Grus Americana), which is listed as endangered by both United States Fish and Wildlife Service (USFWS) and TPWD. A growing population of whooping cranes winter in and near the Aransas National Wildlife Refuge, located adjacent to the Mesquite Bay and the southern and western portions of

San Antonio Bay. This wintering population has grown from a low of only 16 birds in 1941 to a high of 257 birds in December 2007. Detailed research studies by Texas A&M University are underway at this time to identify and better understand factors affecting whooping crane population. Three other migratory birds known to the San Antonio Bay area are listed as threatened by TPWD: the reddish egret (Egretta rufescens), wood stork (Mycteria Americana), and piping plover (Charadrius melodus). The piping plover is also listed as threatened by USFWS.

Endangered and threatened species listed for Comal County include the Black-capped Vireo, Golden-cheeked Warbler, and four additional migratory bird species, two salamanders, an amphipod, and two beetles. Some care may be necessary should water pipelines traverse preferred habit for these endemic species. Black-capped Vireos are insectivorous songbirds that nest in low shrubland thickets where vegetation extends to ground level. Golden-cheeked Warblers prefer habitat consisting of mature oak-juniper woodlands located along steep escarpments and canyons. The listed invertebrate species (amphipod and beetles) are all endemic to karst features or springs, as is the Cascade Cavers salamander. The listed migratory bird species tend to avoid areas of concentrated human development.

Several species listed as threatened by the state may possibly be affected by the project. These include the Texas horned lizard (Phrynosoma cornutum), Texas scarlet snake (Cemophora coccinea lineri), Texas tortoise (Gopherus berlandieri), and timber/canebrake rattlesnake (Crotalus horridus). Many of these reptile species are dependent on shrubland or riparian habitat.

Habitat studies and surveys for protected species and cultural resources may need to be conducted at the proposed lift station sites and along any pipeline routes. Potential wetland impacts, which are limited to pipeline stream crossings, can be minimized by right-of-way selection and appropriate construction methods, including horizontal directional drilling, erosion controls, and revegetation procedures. Compensation for net losses of wetlands would be required where impacts are unavoidable.

All areas to be disturbed during construction would first be surveyed by qualified professionals to determine the presence or absence of significant cultural resources. Cultural resources protection on public lands in Texas is afforded by the Antiquities Code of Texas (Title 9, Chapter 191, Texas Natural Resource Code of 1977), the National Historic Preservation Act (Pl96-515), and the Archeological and Historic Preservation Act (PL93-291).

A specific site for the off-channel reservoir has not been chosen. In choosing a site, key considerations will include minimizing construction and long-term operations costs and minimizing conflicts with streams, highways/roadways, railroads, transmission facilities (water, product, and power), petroleum production, and environmental/cultural resources (e.g., endangered & threatened species habitat, wetlands, and historical/archaeological sites).

The LGWSP for Upstream GBRA Needs relies on existing surface water rights and does not involve any new surface water appropriations. Therefore, freshwater inflows to the Guadalupe Estuary would be the same as the "full water rights use" baseline that is used when calculating surface water supply and evaluating the cumulative effects of regional water plan implementation. Thus graphics showing median inflow and flow frequency are not necessary, as the median values for both Baseline and Lower Guadalupe Water Supply Project for Upstream GBRA needs would be equal in all months.

4C.33.4 Engineering and Costing

The firm yield diversion from the off-channel reservoir used for costing purposes is assumed to be a uniform rate throughout the year. Major facilities required to implement this water management strategy include:

- Canal Intake and Pump Station;
- Transmission Pipeline to Off-Channel Storage;
- Off-Channel Storage;
- Reservoir Intake and Pump Station at Off-Channel Storage;
- Raw Water Transmission Pipeline to Luling;
- Raw Water Pipeline to Lake Dunlap;
- Raw Water Pipeline to New Braunfels;
- Raw Water Pipeline to Western Canyon Project;
- Transmission Lift Stations;
- New or Expanded Water Treatment Plants (Level 3) at Luling, near Lake Dunlap, near San Marcos, at New Braunfels, and at the Western Canyon Project;
- Treated or Raw Water Pipeline from Lake Dunlap to San Marcos; and
- Integration.

The canal intake and pump station are sized to deliver up to 187 cfs through a 3-mile, 96-inch diameter pipeline to an off-channel storage facility in Calhoun County. While a specific off-channel storage facility site has not been selected, it is assumed that an off-channel storage site could be located within three miles of the Calhoun Canal System.

It is important to note that, according to the adopted 2006 SCTRWP, Year 2060 water needs in the upper and middle Guadalupe Basin total about 38,000 acft/yr. The LGWSP for Upstream GBRA Needs project is sized to deliver up to 60,000 acft/yr, approximately 22,000 acft/yr more than the projected needs. This 22,000 acft/yr, delivered as raw water to Lake Dunlap, is held in reserve to meet needs beyond the Year 2060 projected timeline. For consistency, however, cost estimates include treatment and integration for this 22,000 acft/yr.

The estimated costs of the LGWSP for Upstream GBRA Needs are presented in Table 4C.33-2, both in Second Quarter 2007 and Second Quarter 2002 dollars. The estimated total project cost, which includes contingencies, is $656,822,000 in Second Quarter 2002 dollars. With a total annual cost of $73,533,000 (2nd Quarter 2002 dollars) and an available project yield of 60,000 acft/yr, the resulting unit cost is $1,226 per acft (2nd Quarter 2002 dollars). The long-term, post-debt service cost of the project is $434 per acft (2nd Quarter 2002 dollars).

Table 4C.33-2.
Cost Estimate Summary for
Lower Guadalupe Water Supply Project for Upstream GBRA Needs

Item	***Estimated Costs for Facilities (Second Quarter 2007 Prices)***	***Estimated Costs for Facilities (Second Quarter 2002 Prices)***
Capital Costs		
Canal Intake and Pump Station	$8,766,000	$7,315,000
Transmission Pipeline to OCS (96 in dia., 3 miles)	$10,060,000	$6,656,000
Off-Channel Storage Reservoir (Conservation Pool 19,000 acft, 950 acres, 52 ft. msl)	$32,450,000	$26,800,000
Intake and Pump Station at OCS (56.3 MGD)	$15,566,000	$13,043,000
Transmission Pipeline to Luling (60 in dia., 112 miles)	$239,111,000	$177,671,000
Transmission Pipeline to Lake Dunlap (54 in dia., 27 miles)	$36,221,000	$25,396,000
Transmission Pipeline to New Braunfels (33 in dia., 6 miles)	$5,939,000	$4,905,000
Transmission Pipeline to Western Canyon Project (20 in dia., 15 miles)	$9,645,000	$7,966,000
Transmission Booster Stations	$35,087,000	$29,375,000
Spur Pipeline to Luling WTP (16 in dia., 1 mile)	$393,000	$324,000
Spur Pipeline to San Marcos WTP (27 in dia., 20 miles)	$9,039,000	$7,465,000
Spur Pipeline to New Braunfels WTP (27 in dia., 1 mile)	$555,000	$458,000
Luling WTP Expansion (4 MGD)	$5,329,000	$5,329,000
San Marcos WTP Expansion (11 MGD)	$10,952,000	$10,952,000
New Braunfels WTP Expansion (14 MGD)	$14,209,000	$14,209,000
Western Canyon WTP Expansion (6 MGD)	$5,772,000	$5,772,000
New WTP at Lake Dunlap (20 MGD)*	$25,771,000	$21,284,000
Integration (53.6 MGD)	$69,263,000	$69,263,000
Total Capital Cost	**$534,128,000**	**$434,183,000**
Engineering, Legal Costs and Contingencies	$171,397,000	$140,422,000
Environmental & Archaeology Studies and Mitigation	$6,391,000	$5,511,000
Land Acquisition and Surveying (1,817 acres)	$9,924,000	$9,041,000
Interest During Construction (3 years)	$82,839,000	$67,665,000
Total Project Cost	**$804,679,000**	**$656,822,000**
Annual Costs		
Debt Service (6 percent, 30 years)	$54,887,000	$44,851,000
Reservoir Debt Service (6 percent, 40 years)	$3,268,000	$2,622,000
Operation and Maintenance		
Intake, Pipeline, Pump Station	$5,162,000	$4,141,000
Dam and Reservoir	$487,000	$402,000
Water Treatment Plant	$7,857,000	$7,465,000
Pumping Energy Costs (153,952,955 kW-hr)**	$13,856,000	$9,237,000
Purchase of Water (64,198 acft/yr @ 75 $/acft)	$4,815,000	$4,815,000
Total Annual Cost	**$90,332,000**	**$73,533,000**
Available Project Yield (acft/yr)	60,000	60,000
Annual Cost of Water ($ per acft)	$1,506	$1,226
Annual Cost of Water ($ per 1,000 gallons)	$4.62	$3.76

**The 20 MGD WTP at Dunlap is a placeholder for the treatment plant necessary once the need for the water exists.*
*** 0.06 $/kW-hr in 2002 dollars and 0.09 $/kW-hr in 2007 dollars*

4C.33.5 Implementation Issues

Institutional arrangements may be needed to implement the project, potentially including financing on a regional basis.

1. It will be necessary to obtain the following:
   a. TCEQ Storage Permits.
   b. USCE Sections 10 and 404 Dredge and Fill Permits for the reservoir and pipelines.
   c. GLO Sand and Gravel Removal permits.
   d. GLO Easement for use of state-owned land.
   e. Coastal Coordination Council review.
   f. TPWD Sand, Gravel, and Marl permit.
2. Permitting may require these studies:
   a. Assessment of changes in freshwater inflows to bays and estuaries.
   b. Habitat mitigation plan.
   c. Environmental studies.
   d. Cultural resource studies and mitigation.
3. Land will need to be acquired through either negotiations or condemnation.
4. Relocations for the off-channel storage facilities may include:
   a. County roads.
   b. Other utilities.
   c. Product transmission pipelines.
   d. Power transmission lines.

Appendix A

Cost Estimation Procedures
South Central Texas Region

Appendix A
Cost Estimation Procedures
South Central Texas Region

The cost estimates of this study are expressed in three major categories: (1) construction costs or capital (structural) costs, (2) other (non-structural) project costs, and (3) annual costs. Construction costs are the direct costs incurred in constructing facilities, such as those for materials, labor, and equipment. "Other" project costs include expenses associated with implementation activities of the project, such as costs for engineering, legal counsel, land acquisition, contingencies, environmental studies and mitigation, and interest during construction. Capital costs and other project costs comprise the total project cost. Operation and maintenance (O&M), energy costs, and debt service payments are examples of annual costs. Major components that may be part of a preliminary cost estimate are listed in Table A-1. Cost estimating procedures used in the technical evaluation of water management strategies for the South Central Texas Region are summarized in the following sections.

Table A-1.
Major Project Cost Categories

Cost Elements	
Capital Costs (Structural Costs)	***Other Project Costs (Non-Structural Costs)***
1. Pump Stations	1. Engineering (Design, Bidding and Construction Phase Services, Geotechnical, Legal, Financing, and Contingencies)
2. Pipelines	2. Land and Easements
3. Water Treatment Plants	3. Environmental - Studies and Mitigation
4. Water Storage Tanks	4. Interest During Construction
5. Off-Channel Reservoirs	
6. Well Fields	
a. Public	***Annual Project Costs***
b. Irrigation	1. Debt Service
c. ASR Wells	2. Operation and Maintenance (excluding pumping energy)
7. Dams and Reservoirs	3. Pumping Energy Costs
8. Relocations	4. Purchase Water Cost (if applicable)
9. Water Distribution System Improvements	
10. Other Items	

A.1 Capital Costs

Capital costs for elements of a water management strategy are determined from reliable cost information. Cost tables are a useful method for estimating the construction costs for a project element quickly and efficiently. Cost tables have been created for planning cost estimates and are presented and discussed throughout this section. The cost tables report all-inclusive costs to construct. For example, the pump station cost table values include the building, pumps, control equipment, all other materials, labor, and installation costs.

The costs for a project element are typically computed by applying a unit cost from the cost tables to a specific unit quantity. Estimates are reported to the nearest thousand dollars. If previous cost estimates are used, a ratio of the Engineering News Record's Construction Cost Index (ENR CCI)[1] values is applied to update the cost to Second Quarter 2002. For example, based on an average of the monthly index value for the second quarter of 2002 the representative Second Quarter 2002 index value would be 6508. The ENR CCI values are based on construction costs, including labor and materials, averaged over 20 cities. The index measures how much it would cost to purchase a hypothetical package of goods and services compared to what it was in a base year. The index values are reported monthly from 1977 to present. Average annual index values are reported from 1908 to 1976.

Capital cost data and cost estimating procedures are presented and discussed for pumping stations, pipeline, water treatment plants, storage tanks, off-channel reservoirs, well fields, dams and reservoirs, relocations, water distribution system improvements, and settling basins.

A.1.1 Pumping Stations

Intake and transmission pump station construction costs vary according to the discharge and pumping head requirement, and structural requirements for housing the equipment and providing proper flow conditions at the pump suction intake. The cost tables provided herein are based on the station size (in horsepower) necessary to deliver the peak flow rate. Pump station costs are listed in millions of dollars in Table A-2 for a range of horsepower requirements. The costs include those for pumps, housing, motors, electric control, site work, and all materials needed. The costs in Table A-2 were estimated using generalized cost data related to station horsepower from actual construction costs of equipment installed. The cost for an intake

[1] ENR: Engineering News Record, http://www.enr.com/.

Table A-2.
Pumping Station Construction Costs* (Without Intake Structures)

Pump Station (HP)	*Pump Station Cost ($-millions)*	*Pump Station (HP)*	*Pump Station Cost ($-millions)*
< 300	0.80	6,000	6.60
300	0.80	7,000	7.30
400	1.00	8,000	8.00
1,000	2.00	9,000	8.70
2,000	3.30	10,000	9.20
3,000	4.40	15,000	11.70
4,000	5.30	20,000	14.20
5,000	5.90	> 20,000	See Note

*Values are current as of 2nd Quarter 2002.
NOTE: Pump Stations larger than 20,000 HP necessitate an individual cost estimate.

structure is included when pumping from a raw water source, such as a river or reservoir. Based on costs of actual projects, the intake structure cost is estimated as 50 percent of the intake pump station cost. The cost of bringing power to each pump station is estimated as $135/HP, with a minimum cost of $50,000. Power connection costs are calculated for each pump station and for well pumps. Costs for pump stations located at water treatment plants are included in the capital cost table for water treatment plants (Table A-5).

A.1.2 Pipelines

Pipeline construction costs are influenced by pipe materials, bedding requirements, geologic conditions, urbanization, terrain, and special crossings. For technical evaluation of water management strategies, pipeline costs are obtained from Table A-3, which shows unit costs based on the pipe diameters from 12-inches to 120-inches, soil type, and level of urban development. In the case of a high-pressure pipeline (>150 psi), the unit cost is increased by 13 percent for the length of pipe designated as high-pressure class pipe. The unit costs listed in Table A-3 represent the installed cost of the pipeline and appurtenances, such as markers, valves, thrust restraint systems, corrosion monitoring and control equipment, air and vacuum valves, blow-off valves, erosion control, revegetation of right-of-way, fencing, and gates.

Table A-3.
Pipeline Unit Construction Cost within Various Soil Environments*

Pipe Diameter (inches)	Soil		Combination Rock and Soil		Rock	
	Rural ($/ ft)	Urban ($/ ft)	Rural ($/ ft)	Urban ($/ ft)	Rural ($/ ft)	Urban ($/ ft)
12	37	60	47	72	56	84
14	41	68	53	81	64	94
16	47	76	60	92	70	105
18	52	84	67	100	78	114
20	55	89	70	108	82	122
24	61	101	78	121	93	138
27	70	116	89	137	106	157
30	80	129	100	152	120	177
33	93	150	116	178	138	206
36	106	170	133	203	157	235
42	128	206	158	246	192	285
48	148	239	184	287	222	333
54	170	279	213	333	257	386
60	196	319	245	380	294	440
64	219	358	274	426	330	493
66	242	395	305	472	366	547
72	290	471	362	561	434	652
78	318	515	390	614	476	713
84	342	552	426	658	511	763
90	359	583	448	694	539	806
96	422	686	529	819	636	936
102	485	790	608	942	728	1,092
108	548	891	686	1,063	823	1,234
114	614	999	767	1,192	922	1,382
120	692	1,125	866	1,341	1,039	1,556

* Values as of 2nd Quarter 2002.

NOTE: Add 13 percent to unit price for length of pipe with pressure class > 150 psi.

Additional costs are included for pipeline installation when crossing roads, streams, or rivers. Some form of trenchless technology will likely be used to install the pipeline when obstructions (e.g., larger streams, major roads, railways, rivers, and structures) are encountered. The two trenchless technologies included herein are: (1) pipe jacking utilizing boring and/or tunnel techniques to excavate the soil, and (2) horizontal directional drilling. Table A-4 shows costs that are used to estimate pipeline borings and tunneling.

Table A-4.
Crossing Costs with Boring or Tunneling Construction*

Pipe Diameter (inches)	*Tunneling Cost ($/inch diameter/ft)*
≤48	23
54	22
60	21
66	20
72	19
78	18
≥84	17
* Values current as of 2nd Quarter 2002	

A.1.3 Water Treatment Plants

Water treatment plant construction costs shown in Table A-5 are based on plant capacity for seven different types or levels of treatment. It is not the intent of these cost estimating procedures to establish an exact treatment process, but rather to estimate the cost of a general process appropriate for bringing the source water quality to the required standard of the receiving system (i.e., potable water distribution system, a stream in an aquifer recharge zone, or an aquifer injection well). Table A-6 gives a description of the processes involved in each treatment level. The costs in Table A-5 include costs for all processes required, site work, buildings, storage tanks, sludge handling and disposal, clearwell, pumps, and equipment. The costs assume pumping through the plant as follows: Levels 2 through 6 treatment plants include raw water pumping into the plant for a total pumping head of 100 feet, and finished water pumping for 300 feet of total head. Levels 0 and 1 treatments include only finished water pumping at 300 feet of head.

Table A-5.
Water Treatment Plant Construction Costs*

Capacity (MGD)	Level 0 Capital Cost ($)	Level 1 Capital Cost ($)	Level 2 Capital Cost ($)	Level 3 Capital Cost ($)	Level 4 Capital Cost ($)	Level 5 Capital Cost ($)	Level 6 Capital Cost ($)
1	46,200	602,000	3,050,000	3,436,100	6,441,200	2,883,300	4,518,100
10	139,400	2,505,300	8,199,800	13,339,300	25,050,400	15,185,900	23,438,400
50	411,200	7,276,200	20,725,000	45,119,200	77,538,800	55,953,300	86,123,200
75	550,600	10,497,900	26,690,300	64,735,300	107,361,300	80,216,900	125,534,600
100	679,100	12,861,800	31,699,800	78,468,200	143,148,000	105,300,000	163,478,200
150	915,700	19,682,800	41,004,400	117,700,400	214,721,500	154,391,600	237,877,800
200	1,133,900	22,664,900	45,776,500	145,163,700	286,296,000	202,839,900	311,038,500

* Values current as of 2nd Quarter 2002

A.1.4 Storage Tanks

Ground storage tanks may be used for stand-alone storage, as part of a distribution system, or as part of a pumping station. The construction costs for storage tanks are listed in Table A-7 as cost per million gallons of capacity. A storage tank should be included at each transmission pump station along a pipeline. It is assumed that storage tanks at these stations will provide storage for 5 percent of the daily flow.

A.1.5 Off-Channel Reservoirs

An off-channel reservoir is a reservoir located away from a main river channel that receives little or no natural inflow. Off-channel reservoirs are built by placing a dam across a minor tributary or by constructing a ring dike that has no associated tributary. The capacity of these reservoirs is typically used for storing water that is pumped from another location, such as a nearby river. Because natural inflow is an insignificant factor, spillway requirements are minimal. The values in Table A-8 are used for a construction cost estimate for an off-channel reservoir. In this regional water plan, the cost of ring dikes is used for all off-channel reservoirs.

Table A-6.
Water Treatment Level Descriptions

Level 0:	Disinfection Only - This treatment process will be used for groundwater with no contaminants that exceed the regulatory limits. Assumes groundwater does not require treatment for taste and odor reduction and groundwater is stable and requires no treatment for corrosion stabilization. With this treatment, the groundwater is suitable for public water system distribution, aquifer injection, or delivery to the recharge zone.
Level 1:	Groundwater Treatment - This treatment process will be used for groundwater to lower the iron and manganese content and to disinfect. The process includes application of an oxidant and addition of phosphate to sequester iron and manganese. Chlorine disinfection is the final treatment. With this treatment, the groundwater is suitable for public water system distribution, aquifer injection, or delivery to the recharge zone.
Level 2:	Direct Filtration Treatment - This treatment process will be used for treating groundwater from sources where iron, manganese, or other constituent concentrations exceed the regulatory limit and require filtration for solids removal. Assumes turbidity and taste and odor levels are low. In the direct filtration process, low doses of coagulant and polymer are used and settling basins are not required as all suspended solids are removed by filters. The process includes alum and polymer addition, rapid mix, flocculation, filtration, and disinfection. Water treatment with this process is suitable for aquifer injection or for delivery to the recharge zone.
Level 3:	Surface Water Treatment - This treatment process will be used for treating all surface water sources to be delivered to a potable water distribution system. The process includes coagulant and polymer addition, rapid mix, flocculation, settling, filtration, and disinfection with chlorine. This treatment process also applies for difficult to treat groundwater containing high concentrations of iron (greater than 3 mg/l) and manganese requiring settling before filtration.
Level 4:	Reclaimed Water Treatment - This process will be used for treatment where wastewater effluent is to be reclaimed and delivered to a supply system or injected to an aquifer. The concept includes increased treatment of wastewater effluent by phosphorous removal, storage in a reservoir, blending with surface runoff from the reservoir catchment, followed by conventional water treatment. Phosphorous will be removed from the effluent by lime softening including lime feed, rapid mix, flocculation, settling, recarbonation, and filtration. The final treatment assumes ozonation, activated carbon, addition of coagulant and polymer, rapid mix, flocculation, sedimentation, second application of ozone, filtration and disinfection with chlorine. This treatment results in water than can be delivered to a public water system for distribution or injection to the aquifer.
Level 5:	Brackish Groundwater Desalination - Note: This treatment cost does not include pretreatment for solids removal prior to RO membranes. For desalination of a surface water or groundwater containing high solids concentrations, additional solids removal treatment should be included in addition to desalination. (Example: add level 3 treatment costs for a turbid surface water source). This treatment process will be used for treatment of groundwater with total dissolved solids (TDS) exceeding the regulatory limit of 1,000 mg/l. Costs are based on reverse osmosis (RO) membrane desalination of a groundwater with 3,000 mg/l of TDS to lower the treated water TDS below the regulatory limit. The desalination concept includes minimal pretreatment (cartridge filtration, antiscalent addition, acid addition), reverse osmosis membrane system, and disinfection with chlorine. Costs assume desalination concentrate will be discharged to surface water adjacent to treatment plant. With this treatment, the groundwater is suitable for public water system distribution, aquifer injection, and delivery to the recharge zone.
Level 6:	Seawater Desalination - Note:This treatment cost does not include pretreatment for solids removal prior to RO membranes. For desalination of a surface water or groundwater containing high solids concentrations, additional solids removal treatment should be included in addition to desalination. (Example - For desalination of seawater with an intake located on the coast drawing turbid water, cost estimate should include Level 3 treatment plus Level 6). This treatment process will be used for treatment of seawater with total dissolved solids (TDS) exceeding the regulatory limit of 1,000 mg/l. Costs are based on reverse osmosis (RO) membrane desalination of a water with 32,000 mg/l of TDS to lower the treated water TDS below the regulatory limit. The desalination concept includes minimal pretreatment (cartridge filtration, antiscalent addition, acid addition), reverse osmosis membrane system, and disinfection with chlorine. Costs assume desalination concentrate will be discharged to surface water adjacent to treatment plant. With this treatment, the ground water is suitable for public water system distribution, aquifer injection, and delivery to the recharge zone.

Table A-7.
Ground Storage Tank Construction Costs*

Tank Volume (MG)	***Cost ($)***
0.01	17,000
0.05	59,000
0.10	100,000
0.50	340,000
1.00	580,000
2.00	980,000
4.00	1,700,000
6.00	2,300,000
7.50	2,700,000
9.00	3,100,000
* Values current as of 2nd Quarter 2002	

Table A-8.
Off Channel Storage Construction Costs*

Storage Volume (ac-ft)	***Ring Dike Capital Cost ($)***
500	$3,800,000
1,000	$5,400,000
2,500	$8,900,000
4,000	$11,400,000
5,000	$13,000,000
10,000	$18,800,000
12,500	$21,100,000
15,000	$23,300,000
17,500	$25,400,000
19,000	$26,800,000
20,000	$27,500,000
22,000	$29,000,000
25,000	$31,000,000
* Values current as of 2nd Quarter 2002	

A.1.6 Well Fields

The construction costs for public water supply wells are summarized in Table A-9. The costs include well completion, pumps, and other necessary facilities, such as access roads, fencing, and site improvements. The costs for irrigation wells are estimated to be 55 percent of public water supply well costs. Aquifer storage and recovery (ASR) well costs are estimated using the values represented in Table A-10.

Table A-9.
Public and Irrigation Well Construction Costs

Table A-9(a): Public Supply Well Construction Costs*

Well Depth (ft)	Well Capacity (gpm)				
	100	175	350	700	1000
150	$83,000	$126,000	$215,000	$243,000	$303,000
300	$112,000	$160,000	$256,000	$293,000	$362,000
500	$145,000	$200,000	$304,000	$350,000	$431,000
700	$175,000	$236,000	$347,000	$402,000	$493,000
1000	$230,000	$302,000	$427,000	$497,000	$608,000
1500	$322,000	$413,000	$559,000	$656,000	$798,000
2000	$414,000	$523,000	$691,000	$815,000	$989,000

* Values current as of 2nd Quarter 2002.

Table A-9(b): Irrigation Well Construction Costs*

Well Depth (ft)	Well Capacity (gpm)				
	100	175	350	700	1000
150	$46,000	$71,000	$121,000	$139,000	$176,000
300	$61,000	$91,000	$148,000	$175,000	$222,000
500	$76,000	$114,000	$177,000	$214,000	$272,000
700	$88,000	$131,000	$202,000	$247,000	$316,000
1000	$115,000	$169,000	$254,000	$315,000	$403,000
1500	$161,000	$234,000	$340,000	$428,000	$547,000
2000	$206,000	$297,000	$426,000	$540,000	$692,000

* Values current as of 2nd Quarter 2002.

Table A-10.
ASR Well Construction Costs*

Well Depth (ft)	Well Capacity (gpm)				
	100	175	350	700	1000
150	$92,000	$142,000	$247,000	$279,000	$348,000
300	$121,000	$176,000	$288,000	$329,000	$407,000
500	$154,000	$217,000	$336,000	$386,000	$477,000
700	$185,000	$253,000	$380,000	$438,000	$538,000
1000	$239,000	$319,000	$459,000	$533,000	$653,000
1500	$332,000	$429,000	$591,000	$692,000	$843,000
2000	$423,000	$539,000	$723,000	$851,000	$1,034,000

* Values current as of 2nd Quarter 2002.

A.1.7 Dams and Reservoirs

Construction costs for dams and reservoirs are handled individually. Since each reservoir site is unique, costs are based on the specific project requirements. Items included in the estimate consist of the capital (structural) and "other" (non-structural) costs listed in Table A-1. Previous cost estimates are updated to Second Quarter 2002 prices, using the ENR CCI.

A.1.8 Relocations

Large-scale projects, such as reservoirs, may require the use of lands that contain existing improvements or facilities such as utilities, roads, homes, businesses, and cemeteries. The cost estimating procedures account for either the cost of relocation or outright purchase of these types of improvements and facilities. Because the type of improvements and facilities needing relocation vary significantly from project to project, estimating the costs for relocation items is addressed on an individual project basis.

A.1.9 Water Distribution System Improvements

Introducing treated water to a city or other entity may require improvements to the entity's water distribution system, which is comprised of piping, valves, storage tanks, pump stations, and other equipment used to distribute water throughout the entity's service area.

Cost estimate guidelines were developed specifically for distribution system improvements for the City of San Antonio during the Trans-Texas Water Program, which was completed in 1996. These costs were obtained from a 1991 Black and Veatch report to the San

Antonio City Water Board entitled *"Report on Master Plan for Water Works Improvements"* and include estimated costs for improvements to San Antonio's distribution system to convey treated water from the proposed Applewhite project. Using Applewhite Phase 1 capacity of 50 MGD and water distribution costs of $51,750,000 (1991 costs), for strategies producing up to 50-MGD the annual costs were estimated at $1,327,000 per MGD of capacity (Second Quarter 2002). Above 50-MGD capacity, the unit cost is estimated at $819,000 per MGD (Second Quarter 2002).

A.1.10 Stilling Basins

If a water management strategy involves discharging into a water body or perhaps into a recharge structure, it may require a stilling basin. Stilling basin costs, when applicable, were estimated as $3,025 per cfs discharge.

A.2 Other Project Costs

As previously mentioned, "other" (non-structural) project costs are costs incurred in order to implement a project. These include costs for engineering, legal counsel, financing, contingencies, land, easements, surveying and legal fees for land acquisition, environmental and archaeology studies, permitting, mitigation, and interest during construction. These costs are added to the capital costs to obtain the total project cost. The major components of these costs are described below.

A.2.1 Engineering, Legal, Financing, and Contingencies

A percentage applied to the capital costs is used to calculate a combined cost that includes engineering, financial, legal services, and contingencies. The contingency allowance accounts for unforeseen costs and for variances in design elements. In accordance with TWDB guidelines, the percentages used are 30 percent of the total construction costs for pipelines and 35 percent for all other facilities.

A.2.2 Land Acquisition

Land-related costs for a project can typically be divided into two categories: (1) land purchase costs and (2) easement costs. Land areas acquired for various facility types are considered based upon previous project experience. Two types of easements are usually acquired for pipeline construction – temporary and permanent. Permanent easements are those in which the pipeline will reside once constructed. These permanent easements provide access for maintenance and protection from other parallel underground utilities. Temporary easements provide extra working space during construction for equipment movement, material storage, and related construction activities. Pipeline easement costs are estimated using a value of $8,712 per acre ($0.20 per sq-ft), based in large part on recent experience with the Mary Rhodes Pipeline extending from Lake Texana to Corpus Christi. The pipeline area considered in the acquisition cost includes a permanent easement width of 30 to 40 feet, depending upon the pipe size. This value includes costs for the temporary easement.

Land costs vary significantly with location and economic factors. Land costs in Texas are estimated using *"Rural Land Values in the Southwest"*, by Charles E. Gilliland, published biannually by the Real Estate Center at Texas A&M University, College Station, Texas. Other sources of land values, such as county appraisal district records, are also utilized. The land acquisition area estimated for reservoirs includes the acreage inundated by the 100-year or standard project flood.

A.2.3 Surveying and Legal Fees

Ten percent (10 percent) is added to the total land and easement costs to account for surveying and legal fees associated with land acquisition, except for reservoirs and large well fields. The surveying cost for reservoirs is estimated at $50 per acre of inundation.

A.2.4 Environmental and Archaeology Studies, Permitting, and Mitigation

Costs for environmental studies, permitting, and mitigation, as well as archaeological recovery are project-dependent and are estimated on an individual basis using information available and the judgement of qualified professionals. In the case of reservoir strategies, environmental studies and mitigation costs were generally based on 100 percent of the land value for the acreage purchased. The environmental studies and mitigation costs for pipelines were estimated at $25,000 per mile of pipeline.

A.2.5 Interest During Construction

Interest during construction (IDC) is calculated as the cost of interest on the borrowed amount less the return on the proportion of borrowed money invested during construction. In accordance with TWDB guidelines, IDC is calculated as the total of interest accrued at the end of the construction period using a 6 percent annual interest rate on total borrowed funds, less a 4 percent rate of return on investment of unspent funds.

A.3 Annual Costs

Annual costs are those that the project owner can expect to incur if the project is implemented. These costs include repayment of borrowed funds (debt service), operation and maintenance costs of the project facilities, pumping power costs, and water purchase costs, when applicable.

A.3.1 Debt Service

Debt service is the estimated annual payment that can be expected for repayment of borrowed funds based on the total project cost (present worth), an assumed finance rate, and the finance period in years. As specified in TWDB Exhibit B, Section 1.71, debt service for all projects was calculated assuming an annual interest rate of 6 percent and a repayment period of 40 years for reservoir projects and 30 years for all other projects. The debt service factor of 0.06646 or 0.07265 for 40- or 30-year repayment periods is applied, respectively, to the total estimated project costs.

A.3.2 Operation and Maintenance

Operation and maintenance (O&M) costs for dams, pump stations, pipelines, and well fields (excluding pumping power costs) include labor and materials required to operate the facilities and provide for regular repair and/or replacement of equipment. In accordance with TWDB guidelines, O&M costs are calculated at 1 percent of the total estimated construction costs for pipelines, distribution, facilities, tanks and wells, at 1.5 percent of the total estimated construction costs for dams and reservoirs, and at 2.5 percent for intake and pump stations.

Water treatment plant O&M is estimated using Table A-11. The O&M costs listed in Table A-11 include labor, materials, replacement of equipment, process energy, building energy, chemicals, and pumping energy.

Table A-11.
Operation and Maintenance Costs for Water Treatment Plants*

Capacity (MGD)	Level 0 O&M Cost ($)	Level 1 O&M Cost ($)	Level 2 O&M Cost ($)	Level 3 O&M Cost ($)	Level 4 O&M Cost ($)	Level 5 O&M Cost ($)	Level 6 O&M Cost ($)
1	21,000	119,800	214,700	268,700	417,500	295,500	691,200
10	62,300	667,900	894,400	1,049,800	3,101,900	2,323,600	6,099,000
50	234,000	2,505,300	3,817,200	4,294,100	13,718,500	10,889,000	29,529,200
75	338,400	3,817,200	5,725,800	6,680,700	21,472,700	16,190,400	44,048,900
100	441,700	4,711,600	7,276,200	8,349,800	28,629,200	21,440,000	57,700,000
150	645,800	7,634,400	10,736,300	11,928,600	42,944,300	31,890,000	84,900,000
200	847,900	8,946,400	14,315,100	15,507,300	57,259,400	42,290,000	111,900,000

* Values current as of 2nd Quarter 2002

A.3.3 Pumping Energy Costs

In accordance with TWDB guidelines, power costs are calculated on an annual basis using the appropriate calculated power load and a power rate of $0.06 per kWh. The amount of energy consumed is based on the pumping horsepower required.

A.3.4 Purchase of Water

The purchase cost, if applicable, is included if the water management strategy involves purchase of raw or treated water from an entity or a landowner. This cost varies by source.

A.4 Cost Estimate Presentation

For each individual water management strategy total capital costs, total project costs, and total annual costs are presented. The level of detail is dependent on the characteristics of the water management strategy. Additionally, a summary is calculated, showing the cost per unit of water provided by the management strategy, reported as costs per acft and cost per 1,000 gallons of water developed. The individual management strategy cost tables specify the point within the region at which the cost applies (e.g., raw water at the lake, treated water at the municipal and industrial demand center, or elsewhere as appropriate)..

Appendix B

General Assumptions for Applications of Hydrologic Models

Appendix B
General Assumptions for Applications of Hydrologic Models

Following are general assumptions for applications of hydrologic models in the technical evaluations of water management strategies for the South Central Texas Regional Water Planning Group. Pertinent exceptions to, or clarifications of, these general assumptions are enumerated in the subsection of Section 4C summarizing the technical evaluation of each water management strategy.

1. Full exercise of surface water rights.
2. Edwards Aquifer permitted pumpage of 400,000 acft/yr (plus domestic & livestock pumpage of 12,312 acft/yr) subject to Demand Management and Critical Period rules adopted by the EAA. This is consistent with provisions in the EAA statute (SB1477) regarding permitted pumpage of 400,000 acft/yr after year 2007 and with potential critical period management actions reducing pumpage by up to 15 percent to 340,000 acft/yr. Breakdown of use type and geographical distribution of 400,000 acft/yr pumpage is based on proportional reduction of EAA initial regular permits (including any permanent transfers). Edwards Aquifer simulations necessary to determine resultant springflows for inclusion in the WAMs were performed using the Edwards (Balcones Fault Zone) Aquifer Model (GWSIM-IV.[1,2] Note that, by agreement with the TWDB, an Edwards Aquifer supply of 340,000 acft/yr has been assumed for assessment of regional water needs.
3. Operation of Canyon Reservoir at firm yield in accordance with Certificate of Adjudication No. 18-2074E, including subordination of all senior Guadalupe River hydropower permits to Canyon Reservoir.
4. Delivery of GBRA's present contractual obligations from Canyon Reservoir (about 65,000 acft/yr) to points of diversion. Uncommitted balance of firm yield assumed to be diverted at Lake Dunlap.
5. Effluent discharge / return flow in the Guadalupe - San Antonio River Basin as reported for year 1997 and adjusted for SAWS direct recycled water use of 35,000 acft/yr (of which 7,723 acft/yr is consumed for industrial purposes and 18,994 acft/yr is consumed for landscape irrigation purposes). A reuse commitment on the order of 3.5 MGD by the City of San Marcos for steam-electric power generation in Hays County has also been included.
6. Operation of power plant reservoirs (Braunig, Calaveras, and Coleto Creek) subject to authorized consumptive uses at the reservoir, with makeup diversions as needed to maintain full conservation storage to the extent possible subject to senior water rights, instream flow constraints, and/or applicable contractual provisions.

[1] Texas Water Development Board, "Model Refinement and Applications for the Edwards (Balcones Fault Zone) Aquifer in the San Antonio Region, Texas," Report 340, July 1992.
[2] Texas Department of Water Resources, "Groundwater Resources and Model Applications for the Edwards (Balcones Fault Zone) Aquifer in the San Antonio Region," Report 239, October 1979.

7. Desired San Antonio River flows at Falls City gage of 55,000 acft/yr, with seasonally varying minimums under a current SAWS/SARA/CPS draft agreement.
8. Application of Consensus Criteria for Environmental Flow Needs (CCEFN)[3] or site-specific information in the calculation of water potentially available for diversion and/or impoundment as a part of a water management strategy.
9. Operation of Choke Canyon Reservoir / Lake Corpus Christi (CCR/LCC) System at firm yield subject to the Corpus Christi Phase 4 (maximum yield) policy and a TCEQ Agreed Order regarding freshwater inflows to the Nueces Estuary.
10. Historical Edwards Aquifer recharge estimates developed for the Edwards Underground Water District and others[4,5] as updated in the Trans-Texas Water Program[6] and recent studies of the Nueces and Blanco Recharge Basins for the EAA.[7]

The following hydrologic models were used in the technical evaluation of water management strategies for the 2006 South Central Texas Regional Water Plan:

- Guadalupe – San Antonio River Basin Water Availability Model (GSA WAM)[8]
- Nueces River Basin Water Availability Model (Nueces WAM)[9]
- Lower Nueces River Basin & Estuary Model (NUBAY)[10]
- Nueces River Basin Model[11]
- Edwards Aquifer (Balcones Fault Zone) Model (GWSIM-IV)[12]
- Southern Carrizo-Wilcox Aquifer Groundwater Availability Model (SCW GAM)[13]
- Central Carrizo-Wilcox Aquifer Groundwater Availability Model (CCW GAM)[14]

---

[3] Texas Water Development Board, "Guidelines for Regional Water Plan Development, Section 4.2.8," July 2002.
[4] HDR, "Nueces River Basin Regional Water Supply Planning Study, Phase I," Nueces River Authority, May 1991.
[5] HDR, "Guadalupe – San Antonio River Basin Recharge Enhancement Study, Phase I," Edwards Underground Water District, September 1993.
[6] HDR, "Edwards Aquifer Recharge Analyses, Trans-Texas Water Program, West Central Study Area, Phase II," Texas Water Development Board, San Antonio River Authority, March 1998.
[7] HDR, "Pilot Recharge Models of the Nueces and Blanco River Basins," Edwards Aquifer Authority, June 2002.
[8] HDR, "Water Availability in the Guadalupe – San Antonio River Basin," Texas Natural Resource Conservation Commission, December 1999.
[9] HDR, "Water Availability in the Nueces River Basin," Texas Natural Resource Conservation Commission, October 1999.
[10] HDR, "Water Supply Update for the City of Corpus Christi Service Area," City of Corpus Christi, January 1999.
[11] HDR, "Nueces River Basin Edwards Aquifer Recharge Enhancement Study, Phase IVA," Edwards Underground Water District, June 1994.
[12] Texas Water Development Board, "Summary of a GWSIM-IV Model Run Simulating the Effects of the Edwards Aquifer Authority Critical Period Management Plan for the Regional Water Planning Process," July 1999.
[13] INTERA, Inc., "Groundwater Availability Models for the Queen City and Sparta Aquifers," Texas Water Development Board, October 2004.
[14] Bureau of Economic Geology, "Groundwater Availability Model for the Central Part of the Carrizo Aquifer in Texas," Texas Water Development Board, February 2003.

- Southern Central Carrizo System Groundwater Model[15]
- Central Gulf Coast Aquifer Groundwater Availability Model (CGC GAM)[16]
- Hydrologic Simulation Package - Fortran[17]

[15] HDR, "South Central Carrizo System Groundwater Model, SAWS Gonzales-Carrizo Project," San Antonio Water System, November 2004.
[16] TWDB, "Groundwater Availability Model of the Central Gulf Coast Aquifer System: Numerical Simulations through 1999," September 2004.
[17] USGS, "Hydrologic Simulation Program – Fortran User's Manual for Release 11," September 1996.

(This page intentionally left blank.)

Appendix C

Technical Evaluation Procedures for Edwards Aquifer Recharge Enhancement

Appendix C
Technical Evaluation Procedures
for Edwards Aquifer Recharge Enhancement

C.1 Introduction

Several of the recommended water management strategies in the 2006 South Central Texas Regional Water Plan involve the enhancement of recharge to the Edwards Aquifer. Recommended water management strategies in the Regional Water Plan that involve Edwards Aquifer recharge enhancement include Edwards Recharge – Type 2 Project (Section 4C.20), Brush Management (Section 4C.28), and Weather Modification (Section 4C.29). Such recharge enhancement is intended not only to increase springflows protecting endangered species and downstream water uses, but also to enhance the reliability of the Edwards Aquifer as a regional water supply. With regard to enhanced water supply, the Edwards Aquifer Authority (EAA) has adopted rules regarding recharge recovery permits, which define the amount of additional authorized pumpage to which the developer of a recharge enhancement project might be entitled.

For the purposes of regional water supply planning under rules set forth by the Texas Water Development Board (TWDB), recharge enhancement strategies are evaluated herein based on the reliable supply available during the drought of record. In this way, recharge enhancement strategies may be considered by the South Central Texas Regional Water Planning Group (SCTRWPG) on the same basis as surface water supply strategies, such as reservoirs and run-of-river diversions. While numerous studies quantifying recharge enhancement on both long-term and drought average bases have been completed in recent years, the quantification of additional reliable supply based on maintenance of springflows during the drought of record has not always been a part of these studies. Hence, the TWDB's model of the Edwards Aquifer is used in this regional water supply planning effort to simulate aquifer performance subject to recharge enhancement, quantify the associated increase in reliable supply, and allow for more direct comparisons between recharge enhancement and other water management strategies. The following paragraphs provide a brief summary of the technical procedures used for evaluation of Edwards Aquifer recharge enhancement strategies.

C.2 Edwards Aquifer Model

In order to simulate aquifer response to recharge enhancement, the TWDB GWSIM4 Edwards Aquifer groundwater flow model (Figure C-1) is used to make the necessary calculations. It is designed to simulate aquifer response in terms of water levels and springflows for specified recharge and pumping rates. The model was developed by the TWDB in the 1970s[1] as a tool for use in developing a water resources management program for the Nueces and Guadalupe - San Antonio River Basins. Originally, the model operated on an annual timestep and was calibrated to data collected from 1947 to 1971. Major assumptions in the model include: (1) no lateral movement of water from the Glen Rose formation in the Hill Country (Trinity Aquifer-Edwards Plateau); (2) no water movement across the so-called 'bad-water line'; and (3) no leakage from underlying or overlying formations except in an area southeast of Uvalde near Leona Springs.

The TWDB recalibrated the model in the early 1990s[2] with information compiled between 1971 and 1989 and refined the timestep to monthly intervals. The recalibration was based on comparisons of water levels and springflows for 1947 to 1959 and "verified" with 1978 to 1989 data. During the process of adjusting the aquifer parameters for recalibration, the model developers gave special emphasis to minimum flow periods at Comal and San Marcos Springs

[1] Klemt, W.B., Knowles, T.R., Elder, G.R., and Sieh, T.W., "Ground-water Resources and Model Applications for the Edwards (Balcones Faulty Zone) Aquifer in the San Antonio Region, Texas," Texas Water Development Board Report 239, 88p., 1979.
[2] Thorkildsen, D. and McElhaney, P.D.., "Model Refinement and Applications for the Edwards (Balcones Fault Zone) Aquifer in the San Antonio Region, Texas," Texas Water Development Board Report 340, 33p., 1992.

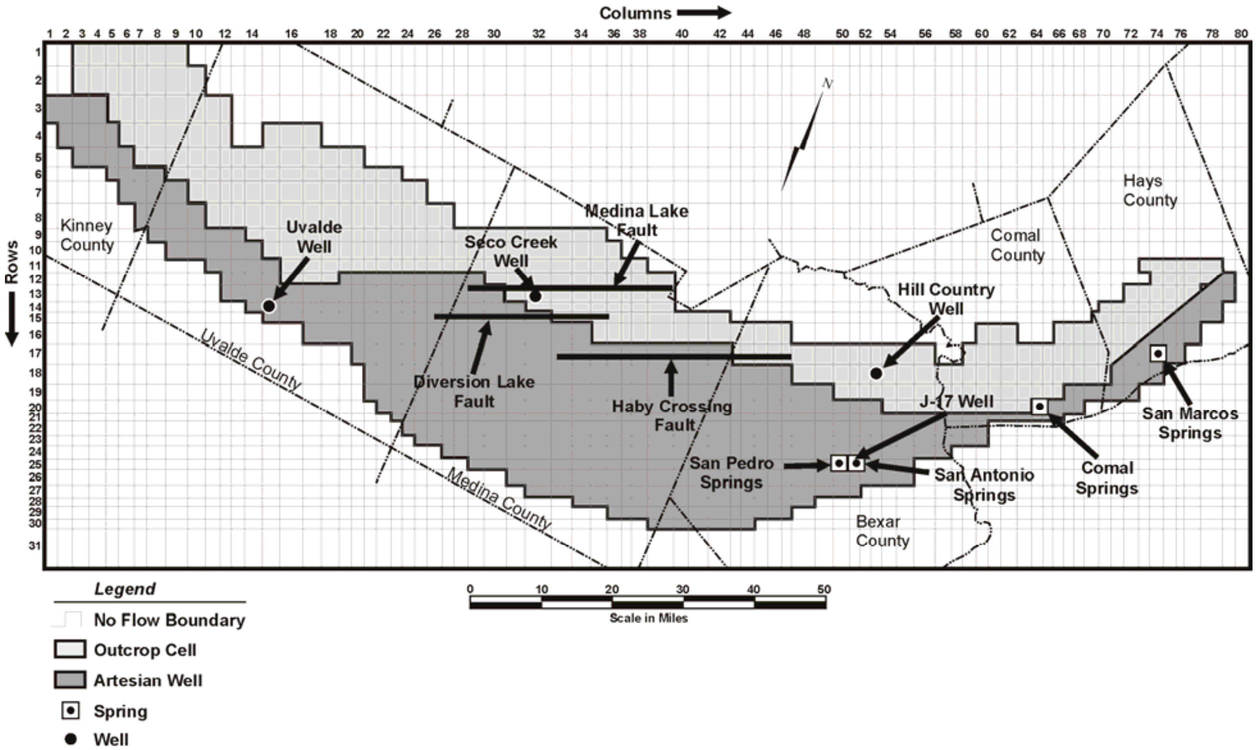


Figure C-1. GWSIM 4 Model for Edwards Aquifer

and water levels at observation well J-17 in San Antonio. The recalibration did not revise any of the major assumptions used in the original model.

All model simulations for this study are for the 1934 through 1989 historical period and have monthly timesteps. The simulation period includes a severe drought in the 1950s (1947 to 1956) and wetter than normal conditions in much of the 1970s and 1980s, except for short, intense droughts in 1984 and 1989. Historical recharge to the Edwards Aquifer is based upon monthly estimates developed by HDR.[3,4] For the most recent version of GWSIM4, the TWDB used estimates of baseline recharge, developed by HDR, that reflect full utilization of current water rights and recharge enhancement associated with all existing projects as if they existed throughout the 1934 to 1989 historical period. The distributions to specific cells in GWSIM4 were made by the TWDB. Annual estimates of baseline recharge are shown in Figure C-2.

[3] HDR, "Guadalupe-San Antonio River Basin Recharge Enhancement Study," Edwards Underground Water District, September 1993.
[4] HDR, "Nueces River Basin Regional Water Supply Planning Study," Nueces River Authority, et al., May 1991.

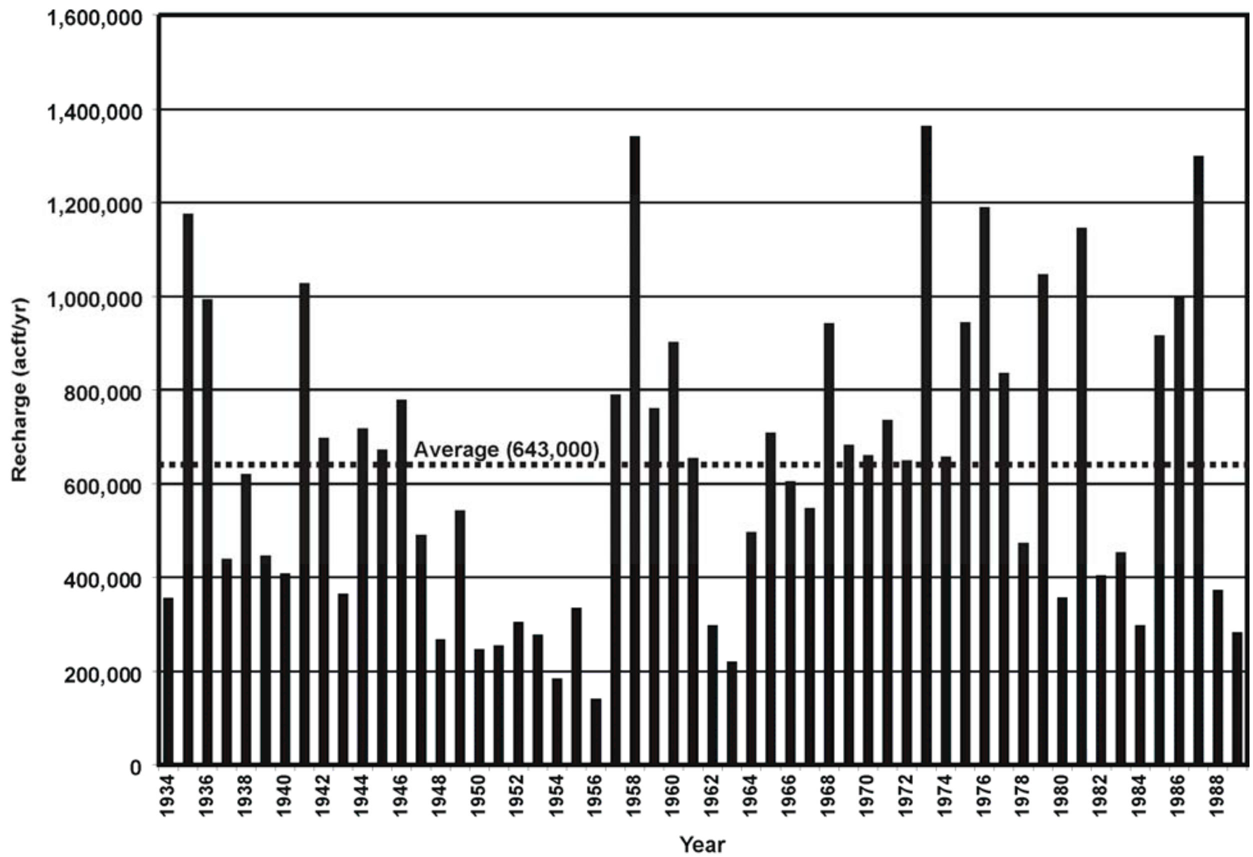


Figure C-2. Edwards Aquifer Recharge

Natural water losses from the Edwards Aquifer model are springflow at Leona, San Pedro, San Antonio, Comal, and San Marcos Springs. Springflow is calculated from aquifer heads at the springs and an aquifer head-springflow rating curve for each spring. Another natural loss is cross-formational leakage in an area southeast of Uvalde. This loss is calculated similarly to springflow. The current version of GWSIM4 includes an estimate of discharge to the Guadalupe River (largely associated with Hueco Springs) and is considered a negative (rejected) recharge by the model. The discharge is estimated from a regression equation of streamflow gains and water levels in observation well J-17.

Pumpage is assigned by category to specific cells in the model by the TWDB, based on the locations of permitted wells. For the baseline permitted pumpage, the total pumpage for irrigation, industrial, and municipal purposes in Kinney, Uvalde, Medina, Bexar, Atascosa, Comal, and Hays Counties, is adjusted to 400,000 acft/yr. Domestic and livestock pumpage does not require permits and totals 12,312 acft/yr. Thus, the total annual pumpage used in the model is 412,312 acft/yr. Annual pumpage is distributed to monthly pumpage values by multiplying the annual pumpage for each category by a monthly distribution factor in accordance with type of use.

C.3 Technical Evaluation Procedure

The technical evaluation procedure used in determining the increase in water supply attributable to a recharge enhancement strategy is based on the definitions, assumptions, and steps summarized in the following paragraphs.

Definitions:

- *Baseline Pumpage:* The sum of the regular permitted industrial, municipal, and irrigation pumpage categories adjusted to 400,000 acft/yr plus the unpermitted domestic and livestock pumpage. The total is 412,312 acft/yr.
- *Baseline Sustained Yield:* The portion of baseline pumpage that will maintain a minimum monthly flow at Comal Springs of 60 (cfs) in one and only one month of the simulation period. This simulation is performed merely to obtain a baseline estimate of aquifer yield for the "no enhanced recharge" case.
- *Sustained Yield with Recharge Enhancement Project(s)*: The sum of the pumpages for the baseline sustained yield scenario plus an across the board increase in pumpage such that the minimum monthly flow at Comal Springs is 60 cubic feet per second (cfs) in one and only one month of the simulation period.
- *Additional Dependable Supply:* The increase in sustained yield attributable to the recharge enhancement project(s).

Assumptions:

- The GWSIM4 Model provides a reasonable simulation of Edwards Aquifer response (in terms of springflow and water levels) to enhanced recharge and various pumpage rates. Note that the EAA, in cooperation with regional, state, and federal interests, has nearly completed the development of a new model of the Edwards Aquifer.
- Minimum Comal Springs discharge of 60 cfs (in one and only one month of the 56-year simulation period) provides a reasonable point of reference for assessment of potential changes in sustained yield of the Edwards Aquifer associated with recharge enhancement. Note that the selection of 60 cfs as a minimum discharge simply provides a point of reference for consistent computations and does not necessarily imply acceptability under the law.
- The increase in sustained yield of the Edwards Aquifer during the drought of record provides a reasonable basis for consideration of recharge enhancement strategies in a manner consistent with other water management strategies in the regional water planning process.

Steps:

1. Make a baseline GWSIM4 simulation with baseline pumpage and baseline recharge. Count the number of months when flow at Comal Springs (Figure C-4) is less than specified value of interest (60 cfs).
2. Make a series of trial and error GWSIM4 simulations with reductions in baseline pumpage until the flow at Comal Springs is 60 cfs in one and only one month of the simulation period. The final run provides the baseline sustained yield of the Edwards Aquifer (Figure C-3).
3. Calculate the enhanced recharge provided by the water management strategy using a surface water model.
4. Add the baseline recharge and the enhanced recharge.
5. Make a series of trial and error GWSIM4 simulations (including enhanced recharge) with the baseline sustained yield pumpage plus across the board increases in pumpage until the flow at Comal Springs is 60 cfs in one and only one month of the simulation period. The final run provides the sustained yield with the recharge enhancement strategy.

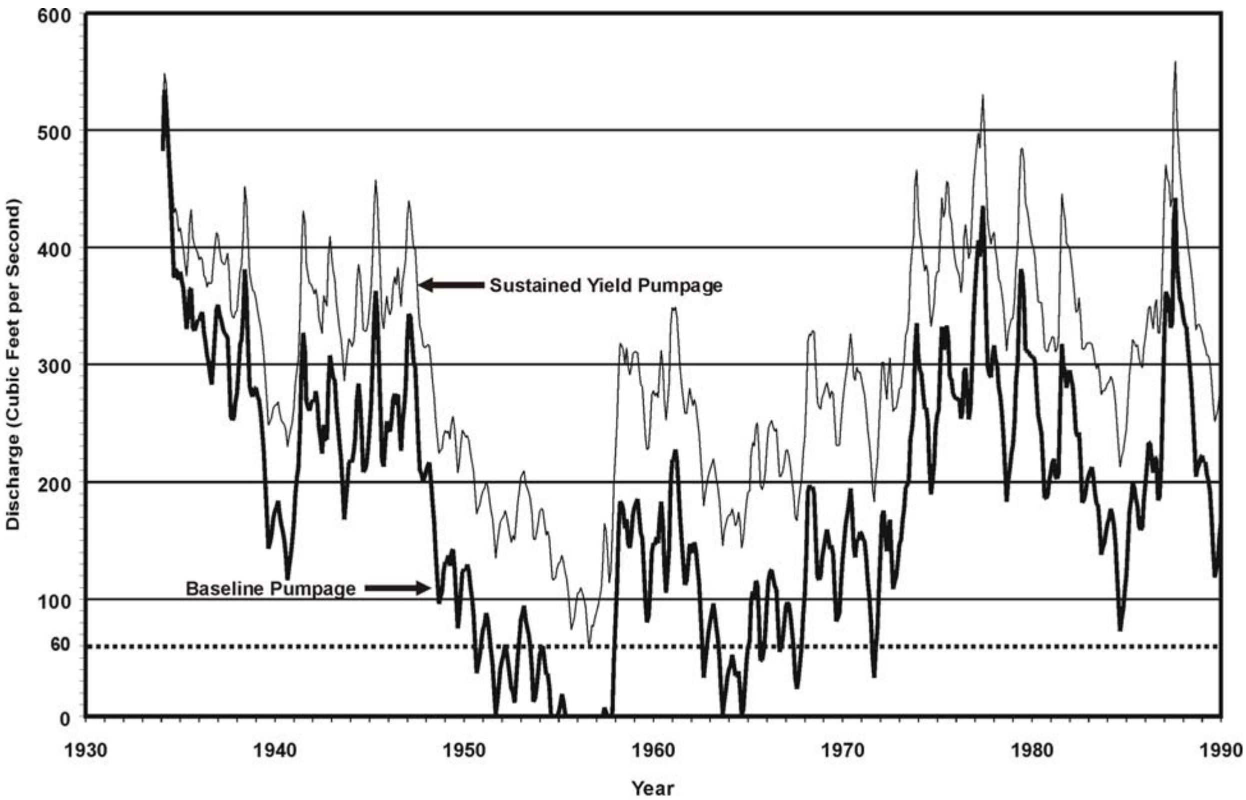


Figure C-3. Comal Springs Discharge Subject to Pumpage Scenarios

6. Calculate the amount of additional dependable supply available during a repeat of the drought of record by subtracting the baseline sustained yield from the sustained yield with recharge enhancement.

Appendix D

HSPF Model Calibration Procedures for Upstream Contributing Land Segments in the Nueces and Blanco Recharge Basins

Appendix D
HSPF Model Calibration Procedures for Upstream Contributing Land Segments in the Nueces and Blanco Recharge Basins

D.1 Model Calibration of the Nueces Recharge Basin Study Area

The original Nueces Recharge study area represented in EAA's Pilot Recharge Models of the Nueces and Blanco River Basins (HDR, 2002) consisted of upper boundaries at the gauging station on the West Nueces River near Brackettville (USGS# 08190500) and the Nueces River at Laguna (USGS# 08190000). The lower boundary was defined by the gauging station on the Nueces River below Uvalde (USGS# 08192000). The study area was subdivided into land segments and river reaches. The model consisted of two land segments in the contributing zone (LS 101 and LS 102), three land segments in the recharge zone (LS 201- LS 203), and three land segments in the confined zone (LS 301- LS 303) as shown in Section 4C.28 (Figure 4C.28-1). The West Nueces River and Nueces River were simulated in HSPF as seven individual river reaches based upon channel loss surveys from previous studies.[1] There were two reaches for the West Nueces River (Reach 11 and Reach 12) and five reaches for the Nueces River, two upstream of confluence with the West Nueces River (Reach 13 and Reach 14) and three below confluence with the West Nueces (Reach 15- 17).

To more accurately model the recharge basin, the upper model boundaries were extended to the upstream contributing, ungaged headwaters of the West Nueces (LS 401) and upstream contributing, ungaged headwaters of the Nueces Rivers (LS 402) as shown in Section 4C.28 (Figure 4C.28-1). Reach 10 was added as the upstream contributing West Nueces River reach associated with LS 401 and Reach 18 was added for the upstream contributing Nueces River reach associated with LS 402. Table D-1 includes the total area of each land segment and assigned land segment identification number. The length of each reach is listed in Table D-2.

The West Nueces River is subject to high flows during storm events, however based on streamflow data for USGS # 08190500−West Nueces River near Bracketville, 74% of the time there is no flow and 86% of the time flow is less than 10 cfs. Due to these extreme flow values, it was difficult to calibrate the HSPF model to replicate both high and low streamflow gage data. Previous loss studies[1] indicate losses of 286 cfs over the recharge zone, 1.7 miles upstream from

[1] USGS, "Streamflow Losses along the Balcones Fault Zone, Nueces River Basin, Texas," Report 83-4368, 1983.

Table D-1. Nueces Recharge Basin Land Segments

Land Segment ID	Description	Area (sq. mi)
401	**Upstream Contributing West Nueces River**	**693.0**
402	**Upstream Contributing Nueces River**	**732.3**
101	West Nueces Contributing	61.4
102	Nueces River Contributing	8.2
201	West Nueces Recharge	141.8
202	Nueces River Recharge	137.4
203	Upper Nueces Recharge	5.2
301	West Nueces Downdip	21.3
302	Nueces River Downdip	40.5
303	Leona Gravels	19.2
	Total	1860.3

Bolded entries indicate updates to the Recharge Model.

Note: Land segment area(s) for LS 101-102, 201-203, and 301-303 obtained from Pilot Recharge Models of Nueces and Blanco River Basins.

Table D-2. Nueces Recharge Basin River Reaches

River Reach ID	Description	Length (miles)
10	**West Nueces River**	**21.3**
11	West Nueces River	12.5
12	West Nueces River	29.5
18	**Nueces River**	**19.1**
13	Nueces River	11.2
14	Nueces River	3.2
15	Nueces River	6.0
16	Nueces River	3.2
17	Nueces River	8.9

Bolded entries indicate updates to the Recharge Model.

Nueces River confluence. Considering the objectives of the evaluations for use in the South Central Texas Regional Water Plan, which are to evaluate potential increase in enhanced recharge due to brush management and weather modification, streamflow greater than approximately 300 cfs would not be available for recharge, and it is therefore not necessary to calibrate to high flow conditions. For example, in this reach of the Nueces River where it traverses the recharge zone, the maximum stream loss, or recharge to the aquifer is 286 cfs.

The new upstream land segment (LS 401) on the West Nueces River was calibrated by comparing simulated streamflow from the HSPF model to historical USGS streamflow data at the gauging station on the West Nueces River near Bracketville (USGS # 08190500) (1934-1998). Streamflow calibration was accomplished using daily streamflow frequency distributions to compare HSPF model and historical streamflow data, presented as the percentage of time that streamflow is exceeded. A frequency distribution comparison of simulated to historical streamflow at USGS # 08190500 is shown in Figure D-1. Given that the simulated streamflow and historical (gaged) streamflow curves are almost identical, it is concluded that the HSPF model performs quite well in simulating the frequency of streamflow available for recharge (Figure D-1).

Linear regression of annual flow values was not deemed an appropriate method of calibration, since extreme high flows not replicated by the HSPF model would be absent from average annual flow amounts resulting in poor annual flow correlation between HSPF model and USGS gage data.

The new upstream Nueces River land segment (LS 402) on the Nueces River was calibrated by comparing simulated streamflow from the HSPF model to historical USGS streamflow data at the gauging station on the Nueces River at Laguna (USGS # 08190000) (1934-1998). Streamflow calibration was accomplished using daily streamflow frequency distribution and linear regression of annual flow values to compare model and historical streamflow data. A frequency distribution comparing daily simulated to historical streamflow at USGS # 08190000 is shown in Figure D-2. Given that the simulated streamflow and historical (gaged) streamflow curves are almost identical, it is concluded that the HSPF model performs quite well in simulating the frequency of streamflow available for recharge.

Linear regression is used to measure how closely the simulated streamflows approximate the historical streamflows over the full range of observed annual values. Ideally, the regression equation would have a slope coefficient of 1.0, an intercept of 0.0, and coefficient of determination (r^2) of 1.0 indicating a perfect match between simulated and historical streamflows. Regression analysis was used to compare annual streamflow simulated by the HSPF model to historical annual streamflow at USGS # 08190000-Nueces River at Laguna with

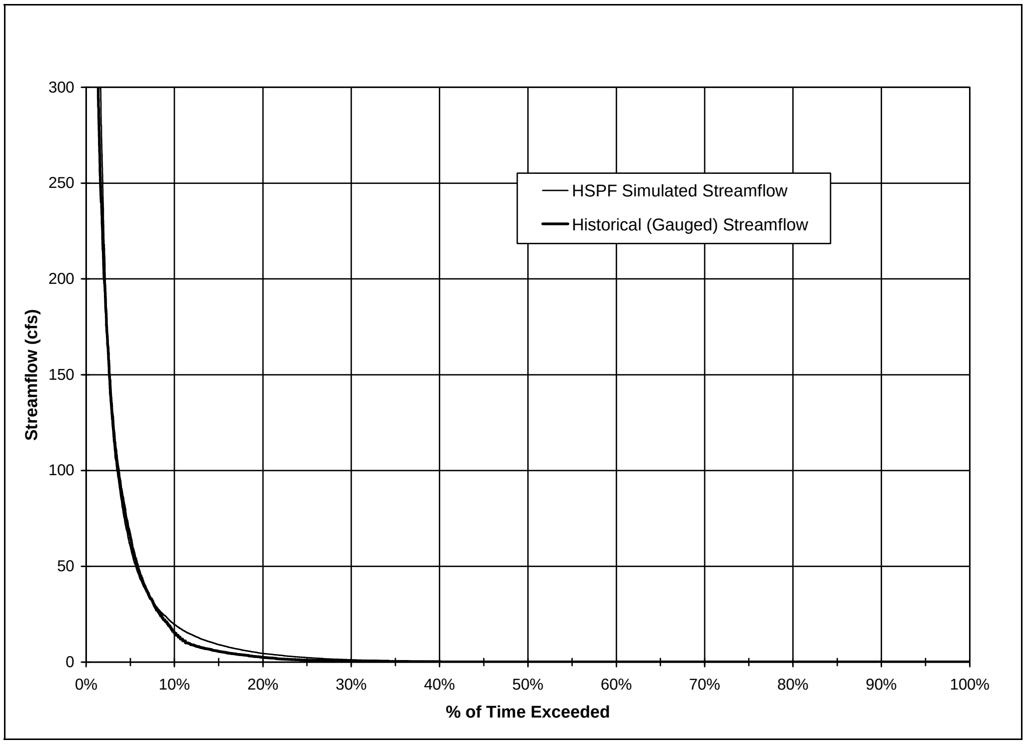


Figure D-1. Streamflow Frequency Distribution of West Nueces River at Bracketville (USGS # 08190500)

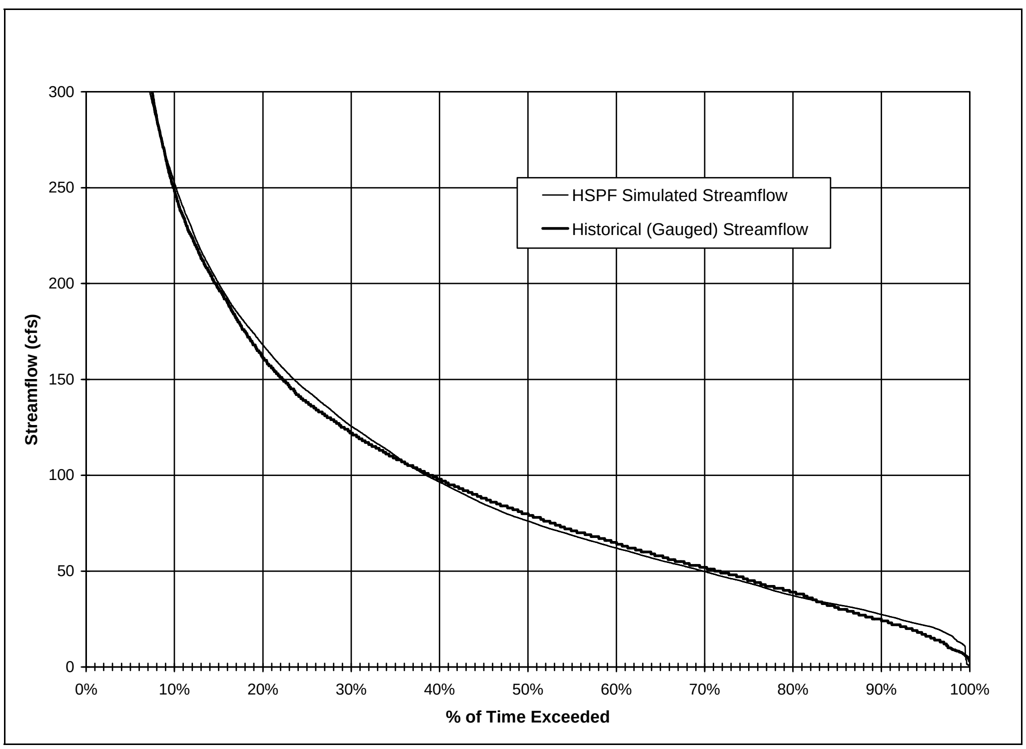


Figure D-2. Streamflow Frequency Distribution of Nueces River at Laguna (USGS # 08190000)

a slope of 0.90 and r^2 value of 0.69 (Figure D-3). The historical annual average streamflow for the Blanco River at Wimberley (1934-1998) was 116,585 acft/yr and the simulated annual average streamflow was estimated at 94,289 acft/yr, a difference of 22,295 acft/yr or about 19 percent. This high percent difference in simulated versus historical annual streamflow is attributable to the HSPF model simulating high flows (>300 cfs) lower than historical gage data. Historical USGS gage data for the Nueces River at Laguna show that streamflow exceeds 300 cfs about 7.5% of the time. Since these high flows would not be able to recharge the Edwards Aquifer in the recharge zone due to recharge limits for the Nueces River[2], it is not essential for the HSPF model to simulate high flows (>300 cfs). The upstream contributing land segments (LS401 and LS402) and corresponding Reaches 10 and 11 were calibrated to USGS gauged data sufficiently to provide reliable estimates of enhanced recharge associated with brush management (Section 4C.28) and weather modification (Section 4C.29).

[2] U.S. Geological Survey, "Streamflow Losses Along the Balcones Fault Zone, Nueces River Basin, Texas", December 1983

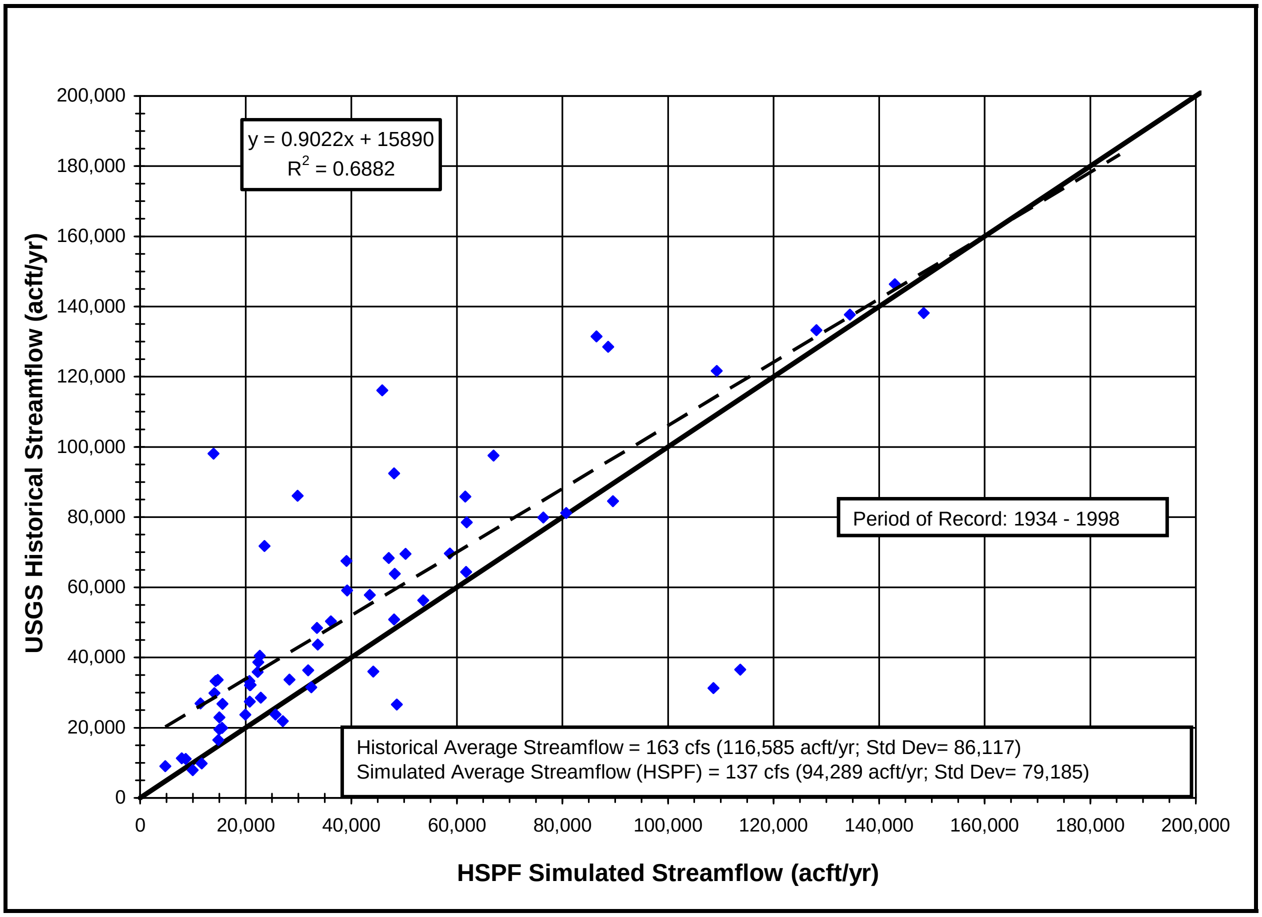


Figure D-3. Nueces River at Laguna- Annual Streamflow Comparison (1934-1998)

D.2 Model Calibration of the Blanco Recharge Basin Study Area

The original Blanco Recharge study area represented in EAA's Pilot Recharge Models of the Nueces and Blanco River Basins (HDR, 2002) consisted of an upper boundary at the gauging station on the Blanco River at Wimberley (USGS # 08171000) and a lower boundary defined by the gauging station on the Blanco River near Kyle (USGS# 08171300). The study area was subdivided into land segments and river reaches. The model consisted of one land segment in the contributing zone (LS 101), four land segments in the recharge zone (LS 201- LS 204), and two land segments in the confined zone (LS 301- LS 302) as shown in Section 4C.28 (Figure 4C.28-2). The Blanco River was subdivided into several river reach segments, based upon channel loss surveys conducted by the Texas Board of Water Engineers.[3] There was one reach segment over the contributing zone (Reach 11) and five over the recharge zone (Reach 12-

[3] Texas Board of Water Engineers, "Channel Gain and Loss Investigations of Texas Streams (1918-1958), 1960.

Reach 16). Flood retardation structures over the ungaged land segments and channel losses for Sink, York, and Purgatory Creeks, which serve to enhance Edwards Aquifer recharge, were also modeled using HSPF.

To more accurately model the Blanco Recharge Basin, the upper boundary was extended to the upstream, contributing, ungauged headwaters of the Blanco River above USGS Gage 08171000-Blanco River at Wimberley by adding one land segment (LS 401) and associated Reach 10. Table D-3 includes the total area of each land segment and assigned land segment identification number. The length of each reach is listed in Table D-4.

The new upstream land segment (LS 401) was calibrated by comparing simulated streamflow from the HSPF model to historical USGS streamflow data at the gauging station on the Blanco River at Wimberley (USGS # 08171000) (1934-1998). Streamflow calibration was accomplished using daily streamflow frequency distribution and linear regression of annual flow values to compare model and historical streamflow data.

A daily streamflow frequency distribution was used to compare daily HSPF simulated streamflows to USGS historical streamflows during high and low flow conditions and presents data as a percentage of time that streamflow is exceeded. A frequency distribution comparing simulated to historical streamflow at USGS # 08171000 is shown in Figure D-4. As in the case for the Nueces Recharge Basin (Figure D-1), it is concluded that the HSPF model clearly performs quite well in simulating the frequency of occurrence of streamflows less than 500 cfs.

Table D-3. Blanco Recharge Basin Land Segments

Land Segment ID	Description	Area (sq. mi)
401	**Upstream Contributing**	**355.1**
101	Gauged Contributing	24.6
201	Gauged Recharge	28.3
202	Sink Creek Recharge	46.3
203	Purgatory Creek Recharge	35.0
204	York Creek Recharge	21.2
301	Gauged Confined	4.4
302	Ungaged Confined	11.5
	Total	526.4

Bolded entries indicate updates to the Recharge Model.

Note: Land segment area(s) for LS 101-102, 201-203, and 301-303 obtained from Pilot Recharge Models of Nueces and Blanco River Basins.

Table D-4. Blanco Recharge Basin River Reaches

River Reach ID	Description	Length (miles)
10	**Blanco River**	**60.3**
11	Blanco River	5.2
12	Blanco River	6.5
13	Blanco River	1.5
14	Blanco River	0.5
15	Blanco River	3.2
16	Blanco River	2.2

Bolded entries indicate updates to the Recharge Model.

Linear regression is used to measure how closely the simulated streamflows approximate the historical streamflows over the full range of observed annual values. Ideally, the regression equation would have a slope coefficient of 1.0, an intercept of 0.0, and coefficient of determination (r^2) of 1.0 indicating a perfect match between simulated and historical streamflows. Regression analysis was used to compare annual HSPF simulated streamflow to historical annual streamflow at USGS # 08171000-Blanco River at Wimberley with a slope of

0.94 and r^2 value of 0.75 (Figure D-5). The historical annual average streamflow for the Blanco River at Wimberley (1934-1998) is 102,784 acft/yr and the simulated annual average streamflow is 92,481 acft/yr, a difference of 10,302 acft/yr or about 10 percent.

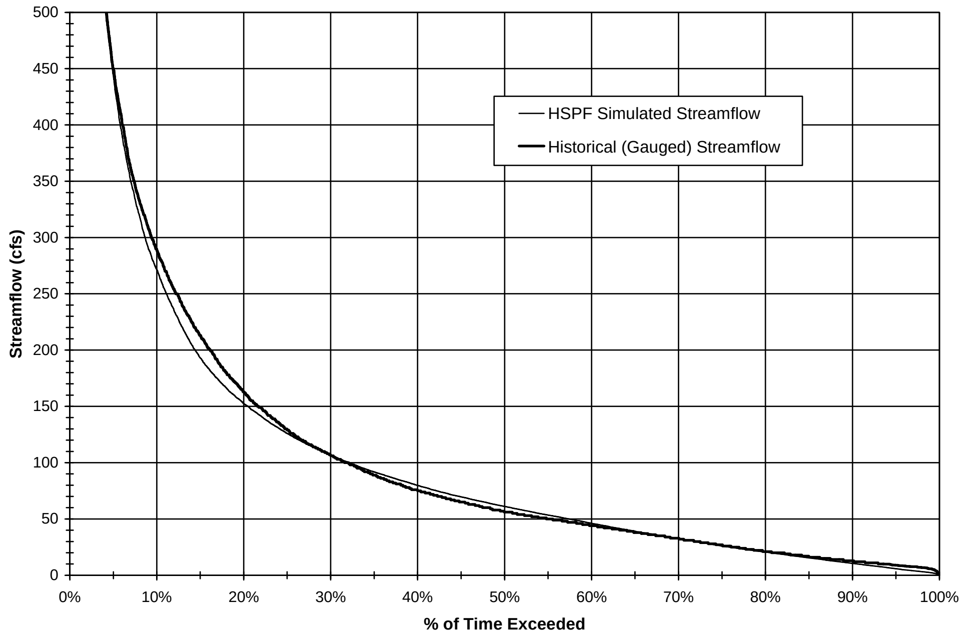


Figure D-4 Blanco River at Wimberley Frequency Distribution (Average Daily Flow, 1934-1998)

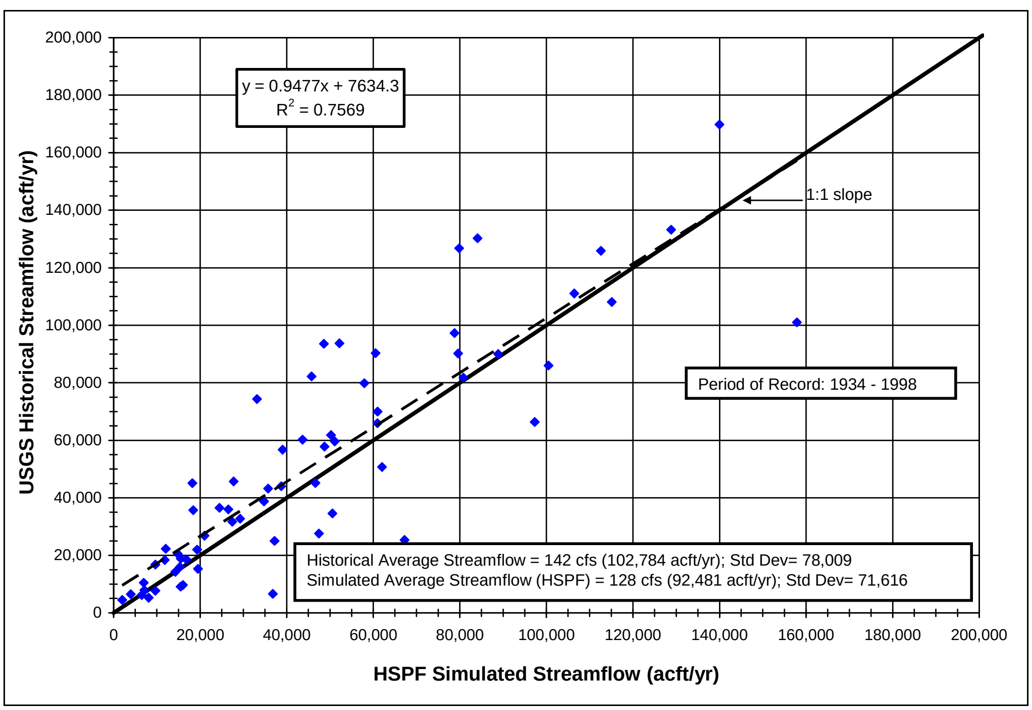


Figure D-5 Blanco River at Wimberley- Annual Streamflow Comparison (1934-1998)

(This page intentionally left blank.)